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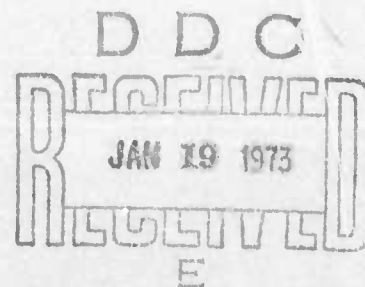
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TECHNICAL DOCUMENT 196

ANTENNA AND RF DISTRIBUTION SYSTEMS APPROACHES TO MEET AN/VCC-2 COMMUNICATIONS REQUIREMENTS ON AMPHIBIOUS SHIPS

L. M. Peters and I. C. Olson

4 October 1972



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INTRODUCTION

The U. S. Navy has installed Radio Engineering Products (REP) AN/VCC-2 communications equipment aboard 21 of its major amphibious ships and one heavy cruiser for use by the Navy and the Marine Corps. The VCC-2 is a multichannel, FM, duplex system operating in the vhf band (30-76 MHz). Its RT-524/VRC transceivers have been modified to increase their bandwidth to provide the multichannel capability. The VCC-2 system uses two TH-81/GCC telegraph-telephone terminals. Each terminal provides one telephone order-wire, four telephone message channels, and four telegraph channels. The purpose of the equipment is to provide ship-to-ship and ship-to-shore vhf communications during amphibious operations.

The term "rf distribution system" will hereafter in this report refer to the entire rf circuit beginning at the transceiver output and ending at the antenna. This includes patch panels, cables, multicouplers, and diplexers. The antenna and rf distribution system for the VCC-2 radio equipment, including its interface with other shipboard vhf systems, had not been addressed by Navy systems designers prior to shipboard installation. Thus, no master guidance plan was available to the ships, even though most ships were required to install their own antennas and distribution systems. In fact, all ships did install their own VCC-2 equipment.

The absence of a master installation plan inevitably resulted in variation in AN/VCC-2 rf installations. The VCC-2 system performance aboard most ships has suffered accordingly. For the optimum performance of all vhf communication systems, it is vital that the VCC-2 equipment either be properly integrated into the present vhf shipboard antenna and rf distribution systems, or that these systems be modified to provide for an efficient integration.

The purpose of the study reported here was to (1) determine the operational requirements for the VCC-2 system, (2) determine what antenna and rf distribution systems are in shipboard service, (3) determine whether these systems are meeting the requirements, (4) investigate the possible use of the REP vhf antenna/multicoupler combination in a VCC-2 rf system, (5) determine what other antenna and rf system approaches are available, (6) perform an analysis of all system approaches as a basis for comparison and recommendation, and (7) provide a source of design guidance for the fleet.

This report consists of two separate phases. The first phase reports information obtained from visits to various commands having knowledge of the VCC-2 system and from a personal survey of shipboard installations made to determine what now exists in the fleet. The second phase describes the development of various vhf antennas and rf distribution system approaches for the AN/VCC-2 system and the calculation of a predicted maximum range in order to establish both a comparison basis and design criteria. Results of the survey and the systems development with calculations are presented together with conclusions and recommendations based on these investigations.

BACKGROUND

The AN/VCC-2 vhf-FM duplex, multichannel communications equipment has been installed aboard eleven ships homeported on the West Coast and eleven ships homeported on the East Coast. These ships include four major amphibious classes: LCC, LPH, LPD, and LP^A; and one heavy cruiser, class CA. The VCC-2 equipments were installed aboard each ship by ship's force. All but six ships installed their own antenna and rf distribution systems. The rf systems aboard these six ships were fitted at navy shipyards. No ship had the benefit of a master guidance plan for the installation of a vhf-rf distribution system for the VCC-2 equipment that would effectively interface with other vhf systems. Each ship was left to her own resources to best locate and mount her antennas and multicouplers, if any.

Space limitations aboard most ships severely restrict the allowable locations for antennas of any type. If the antennas are large, this can make placement even more difficult. Antennas have electrical restrictions in that they should be mounted in a location where they will have an omnidirectional radiation pattern and be as far from other antennas or superstructures as possible. The distance of separation from other antennas or superstructures should be as large as possible, to minimize electrical interference and antenna radiation-pattern null depths. All antennas must be mounted vertically, and some should be provided with their own ground plane, if required. Each of the above restrictions applies to the three separate types of vhf antennas presently being used for the VCC-2 system. The restrictions are severe, especially when omnidirectional coverage is required.

The VCC-2 requires two antennas which are used simultaneously for receive and transmit at different frequencies. One multicoupler would be able to feed one antenna in order to replace the four antennas needed for operation of two VCC-2 equipments. Only one vhf multicoupler, the AN/SRA-60(V), is now available for shipboard application. Tests have been performed on another multicoupler, the REP F64685, but its performance appears to be unacceptable for shipboard installation as reported in an NELC Technical Note.¹ However, the REP antenna/multicoupler combination will be considered as a possible design approach.

For a ship to communicate effectively with its VCC-2 equipment, its antenna and rf distribution system must not limit the operational performance of the system. There are two categories of constraints, physical and operational, that can affect this performance.

Physical constraints refer to the limitations on the antenna and rf distribution equipments (multicouplers, patch panels, and cables) due to their

¹This material was covered in an informal document intended primarily for use within the Center: NELC Technical Note 1942, *Test Evaluation of Radio Engineering Products VHF Multicoupler Model F64685 and VHF Antenna Model F62420*, by H. W. Guyader and I. C. Olson, 4 October 1971

design and placement aboard the ship. Operational constraints refer to three basic areas: attainable communication range, performance reliability, and circuit adaptability requirements.

The first operational constraint is a function of antenna radiation pattern and system losses. Range is limited by the summation of all losses in the entire communication link. This includes cable attenuation, multi-coupler insertion loss, mismatch loss, antenna efficiency, and propagation path attenuation. All losses being equal, the range as a function of azimuth will be dependent on the antenna pattern. An analysis of the effect of these losses on range is presented later in the report.

The second operational constraint is the performance reliability requirement. This constraint is imposed by the necessity for the ship to maintain continuous communication contact with another ship or shore station regardless of its orientation. If contact is lost, it can cause the loss of message traffic on eight telephone channels and eight teletype channels. Performance reliability also applies to the quality of the transmission. Limitations to quality are imposed by interference due to fading, intermodulation, cross-modulation, and locally generated static.

The third constraint, adaptability, relates to the distribution system makeup and the antenna system radiation characteristics. The optimum rf distribution system would be one designed to provide the operator information on circuit performance and means of compensating for deficiencies, such as a poor antenna radiation pattern.

The VCC-2 rf distribution systems now in service with the fleet and possible different systems can be examined and analyzed for comparison of their capability to meet these constraints. The one best system, if it exists, should be able to provide for optimum performance not only for the VCC-2, but also for other vhf communication systems aboard.

APPROACH

The approach covered in the first phase of this report was (1) to determine the operational performance requirements for the VCC-2 shipboard system and (2) to examine the antenna and rf distribution systems now in shipboard service and ascertain if the ships are meeting these requirements.

Commands having knowledge of the VCC-2 system were visited to better determine the operational requirements. These commands include COMPHIBPAC, COMPHIBLANT, CGFMFLANT, and NAVSEC Headquarters.

The San Diego Naval Station and the Long Beach and Portsmouth Naval Shipyards were visited to gather specific antenna information.

An on-board survey of as many ships having VCC-2 installations as possible was conducted. In each case, contact was made with the ship's Communications Officer or his representative, who provided needed information for the survey and made available his people who were most knowledgeable of the system. The survey consisted of a visual inspection of the VCC-2 installation in general and the antenna and rf distribution

systems in particular. The types of antennas, their positions on the ships, and the ground planes provided, if any, were carefully noted. Questions were asked concerning the system's overall operational performance and what specific problems existed with the rf distribution. Generally, information about ship-to-ship and ship-to-shore ranges, antenna coverage, circuit reliability, and equipment restrictions was sought. Information on the problems of fading, interference, and loss of circuit was also collected. The results are reported later in the report.

The second phase of the approach was to investigate various other antenna and rf distribution system approaches, including the REP vhf antenna/multicoupler (F62420/F64685) combination, and perform a theoretical analysis of these approaches and of those in service to predict the maximum operational range performance that can be expected from each. Also, the analysis serves as a basis for system comparison and as a source of design guidance to the fleet. The approach was also to determine the extent to which circuit adaptability can be provided. "Adaptability" refers to the ability to substitute or replace a piece of equipment into the rf circuit as needed to keep that circuit up or to increase the circuit's efficiency. The optimum rf system would provide the operator the capability to perform a simple diagnostic performance evaluation of his circuit and to allow antenna and/or other equipment or frequency tradeoffs to compensate for any deficiencies.

SYSTEM DESCRIPTIONS

INDIVIDUAL SHIPBOARD SYSTEMS

From a thorough investigation of existing equipment, seven possible vhf-rf distribution approaches for the VCC-2 shipboard configuration have evolved for analysis (see figure 1). A general description of each shipboard system is presented here. The order of presentation has no special significance. The performance capability of each of these systems is presented later.

1. System #1 consists of an AS-1729 antenna connected directly to the RT-524 transceiver output with a coaxial cable. The AS-1729 is a 10-foot base-tuned, center-fed, vertically polarized whip antenna having an omnidirectional azimuthal radiation pattern. It is not a broadband antenna, but covers the 30 to 76 MHz band in ten pretuned band segments that can be selected either remotely (by the RT-524) or manually. It has a maximum power rating of 70 watts. This is the typical shipboard system except for the LCC's and some LPH's.
2. System #2 consists of the AS-1729 antenna described under system #1 and the REP CU-1857/TRC diplexer. The diplexer is an antenna coupler that uses notch filters to permit the operation of two RT-524 transceivers into one antenna. It allows for simultaneous reception and transmission at two different frequencies in the 30 to 76 MHz band. Impedance for the diplexer is a nominal 50 ohms unbalanced, and the maximum transmitter power is 130 watts. When the AS-1729 antenna is used with the CU-1857 diplexer, the

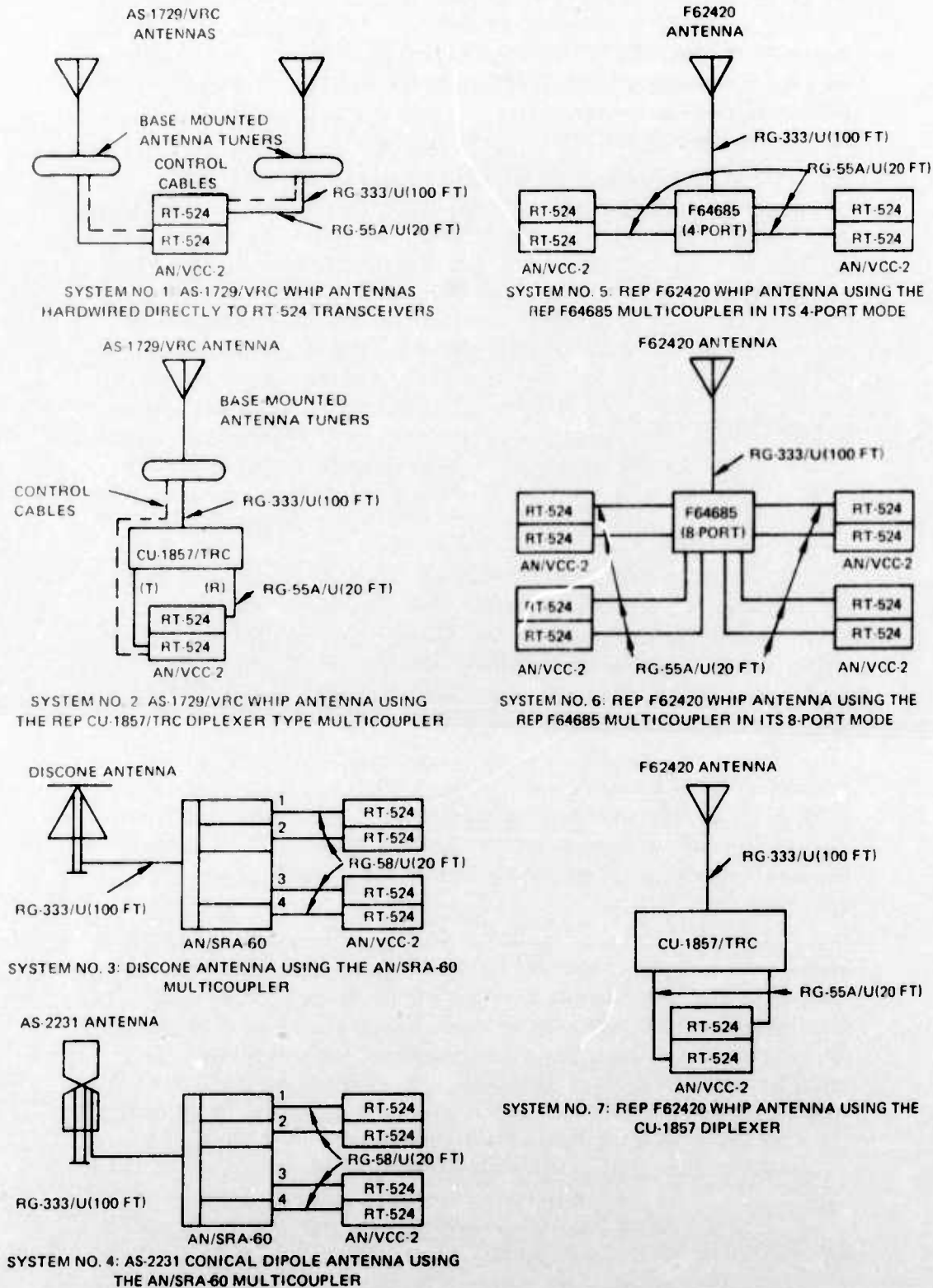


Figure 1. AN/VCC-2 antenna rf distribution approaches.

out-of-band mismatch loss of the antenna must be considered. A description of this loss and the measurement procedure for it, with results, are given in Appendix A. The AS-1729 is a tunable antenna, automatically remotely tuned by a RT-524 transceiver. System #2, however, uses two transceivers per one antenna and so that antenna can be tuned by only one of the two RT-524's, namely the one transmitting.

3. System #3 consists of the DECO (a division of Westinghouse Electric Corporation) AN/SRA-60(V) Antenna Coupler Group and the NELC-designed broadband, 30 to 76 MHz, discone antenna. The Antenna Coupler Group can connect a combination of four or eight vhf transceivers to one or two associated broadband antennas. Each configuration of four antenna couplers (eight possible per group) operates into a single broadband antenna. All antenna couplers are built as drawer assemblies and are installed in an electrical equipment cabinet which has the power component installed in its base. The coupler can operate with transmitters having power outputs as high as 100 watts average or 100 watts peak envelope power (PEP) for each channel. Channel isolation of 40 dB or greater is provided by a frequency separation of 1.5 percent. For all frequencies separated 7 percent or more above 53 MHz, the isolation is 80 dB or greater and 75 dB or greater below 53 MHz.

The discone antenna is vertically polarized and provides an omnidirectional azimuthal pattern coverage. The rf power-handling capability of the antenna is sufficient to be operated with the AN/SRA-60(V) Coupler Group. This system is used only on USS GUADALCANAL (LPH 7).

4. System #4 consists of the DECO AS-2231/SRA-60(V) Antenna Assembly and the DECO AN/SRA-60(V) Antenna Coupler Group combination. The antenna assembly is a vertically polarized conical dipole that provides omnidirectional azimuthal coverage over the frequency range of 30 to 76 MHz. The rf power-handling capability of the antenna is 6400 watts PEP, or 400 watts average power for continuous operation. The Antenna Coupler Group is described under system #3. This system is used on the LCC's and some LPH's.

5. System #5 consists of the REP F64685 antenna coupler and F62420 antenna. The coupler is intended for use with 1 to 8, 30 to 76 MHz, 65-watt maximum power transceivers operating into one, two, or three omnidirectional constant-impedance antennas, such as the F62420. All terminal impedances are 50 ohms. The system consists of seven hybrid circuits, seven balancing resistors, and patching cords. It can be used either as a single eight-port or as a dual four-port multicoupler, depending on how the cords are placed in the patching panel. One, two, or three antennas can be used with the eight-port or with each four-port multicoupler. In system #5, the coupler is used in its dual four-port mode as shown in figure 1.

The F62420 antenna is a broadband whip vertically polarized with an omnidirectional radiation pattern and a maximum power dissipation of 150 watts. The bottom of the antenna is an aluminum tube containing a resistive network to provide a constant 50-ohm match to a coaxial cable over the frequency band of 30 to 76 MHz.

6. System #6 is the same as system #5, except that the F64685 antenna coupler is now operated in the single eight-port mode. This will cause the insertion loss through the coupler to increase.
7. System #7 consists of the REP CU-1857/TRC diplexer of system #2, but uses the REP F62420 antenna of systems #5 and #6.

COMBINATIONS

For analysis, it is assumed that any of the seven systems described above could be present aboard a given ship. A second ship, in communication with the first, could also have one of the systems aboard. Thus there are 28 possible system-to-system combinations in ship-to-ship and ship-to-shore communications. Figure 2 is a matrix with the seven systems comprising both its rows and its columns. The numbers 1 through 28 indicate possible combinations. The letters NA ("not applicable") mean either that that combination is not possible or that it has already been included by a numbered box. These 28 possible system combinations will be analyzed to predict the maximum worst-case range that can be expected from each.

	<div>AS-1729 (Hardwire)</div> <div>AS-1729 and CU-1857</div> <div>Discone and SRA-60</div> <div>AS-2231 and SRA-60</div> <div>F62420 and F64685 (4-port)</div> <div>F62420 and F64685 (8-port)</div> <div>F62420 and CU-1857</div>						
AS-1729 (Hardwire)	1	2	3	4	20	23	26
AS-1729 and CU-1857	NA	5	6	7	8	24	27
Discone and SRA-60	NA	NA	9	10	11	12	28
AS-2231 and SRA-60	NA	NA	NA	13	14	15	16
F62420 and F64685 (4-port)	NA	NA	NA	NA	17	18	19
F62420 and F64685 (8-port)	NA	NA	NA	NA	NA	21	22
F62420 and CU-1857	NA	NA	NA	NA	NA	NA	25

NA = Not Applicable

Figure 2. AN/VCC-2 antenna rf distribution systems ship-to-ship/shore combinations matrix.

SYSTEM ANALYSIS PROCEDURE

Each of the 28 possible ship-to-ship/shore vhf communication systems indicated by the matrix of figure 2 is evaluated to predict the maximum range that can be expected from each system. This range considers two-way communication under the worst-case conditions. Greater range might be achieved for either the transmit or receive mode of the full duplex circuit, when using the CU-1857 diplexer, because of mismatch loss on the receive circuit. As is explained later, this is because there are two different values of mismatch loss that must be considered depending on whether the receive frequency is above or below the transmit frequency. The maximum effective range of a vhf communications link is an important criterion for system comparison.

The curve in figure B1 (in Appendix B) displays field strength in dB/ μ V/m (ground wave) versus distance in statute miles over seawater for several frequencies, assuming 1-kW radiated power from a lossless short monopole on the earth's surface. This curve can be used to determine the maximum range for a communications link. To use the curve, some assumptions are needed. The assumptions made for all systems are:

1. The received signal necessary for a maximum range is -87 dBm for multichannel voice in a 50-ohm system for a constant 12 dB S+N/N ratio at the receiver's audio output.²
2. The available power output of the RT-524 transceiver is 40 watts (+46 dBm).
3. No external noise, i.e., receiver noise, limits sensitivity.
4. Land/water interface effect on field strength is negligible as the link is with beach units at the edge of the seawater.

The range-analysis equation used for converting the given information to that necessary for using the range-prediction curve is:

$$E(\text{dB}/\mu\text{V}/\text{m}) = V_{\text{rec}}(\text{dB}/\mu\text{V}) + 4.8 - 20 \log(\lambda/2\pi) + RG_{\text{rec}} + \alpha_r + \beta_r + \gamma_r + 14 + RG_{\text{xmt}} + \alpha_T + \beta_T \quad (1)$$

where:

E = electric field strength in dB/ μ V/m

V_{rec} = receiver sensitivity in dB/ μ V

λ = wavelength in meters

RG_{rec} = receive antenna's relative gain in dB/1/4 λ monopole.

RG_{xmt} = transmit antenna's relative gain in dB/ 1/4 λ monopole.

α_r = cable attenuation of receive system in dB

α_T = cable attenuation of transmit system in dB

²Kelly and Morrow, *Fleet Marine Force Multiplex (FMF MUX)*, ECAC - STP-88, August 1968, p. 3-35.

- β_r = multicoupler insertion loss of receive system in dB
 β_T = multicoupler insertion loss of transmit system in dB
 γ_r = out-of-band mismatch loss of AS-1729 antenna in dB

Equation (1) above is derived in Appendix B. With the assumptions above and equation (1), the curve of figure B1 can be used to determine the predicted maximum range for the 28 possible combinations. Tables of values for the parameters in equation (1) and a sample calculation for combination #3 are included in Appendix B. The ranges for all combinations are plotted in figures 3A through 3G.

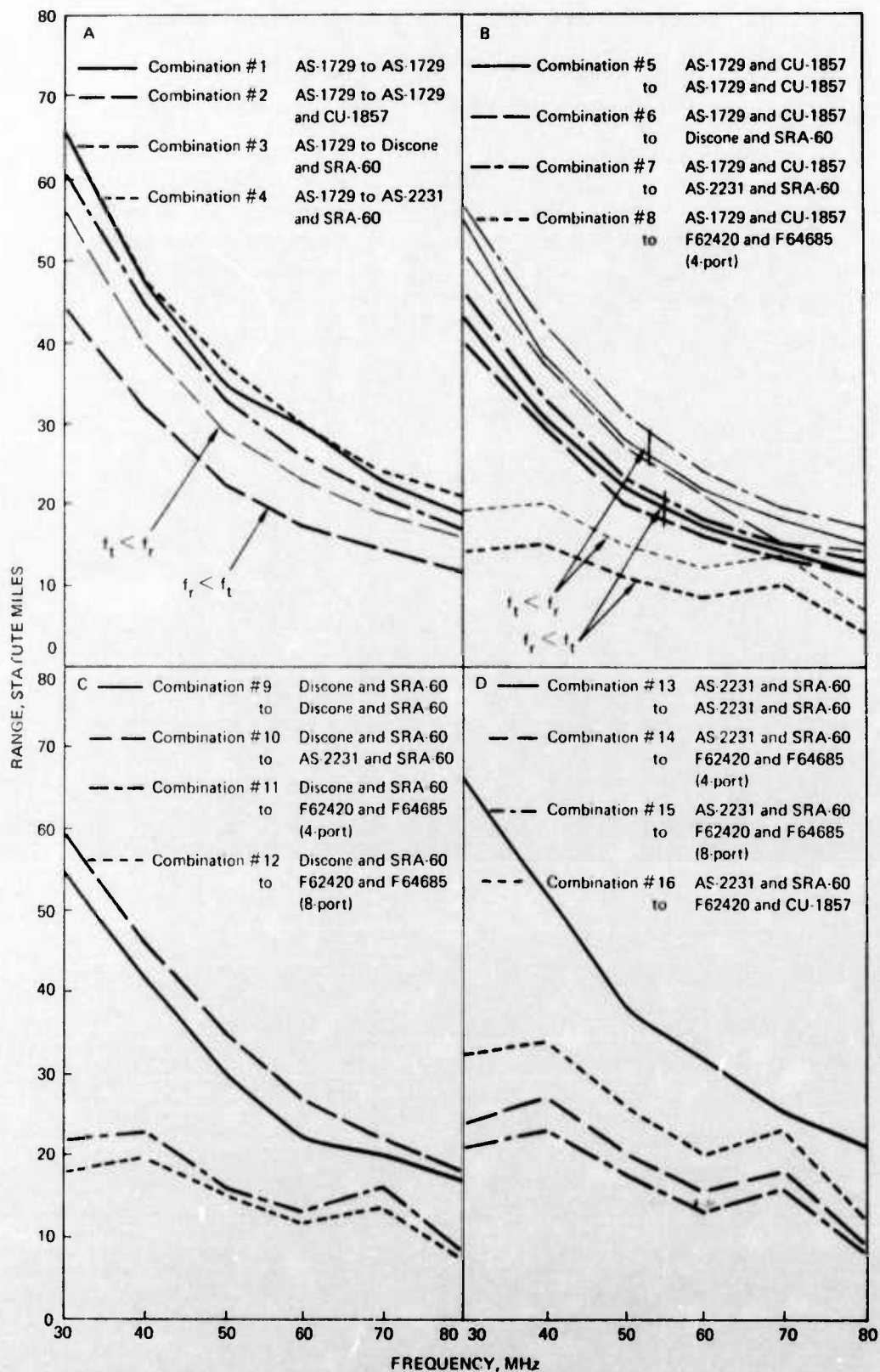


Figure 3. AN/VCC-2 vhf-FM maximum range predictions for ship-to-ship/shore communications, using various antenna and rf distribution system approaches (ground wave over seawater, +46 dBm of available power, -87 dBm at receiver).

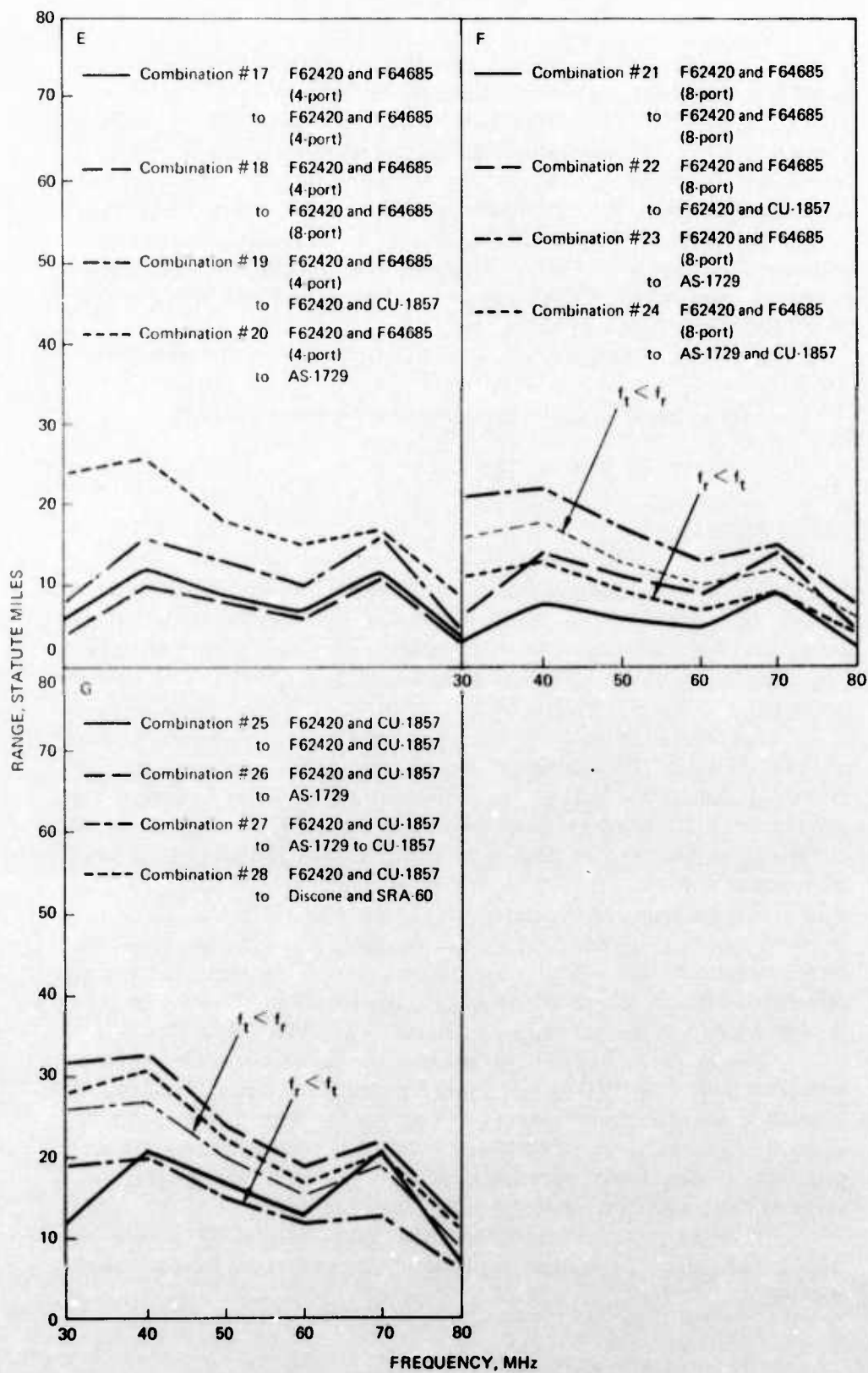


Figure 3. (Continued).

ANTENNA MISMATCH LOSS

The range analysis equation given above includes a term for the out-of-band mismatch loss to a 50-ohm system for the AS-1729 antenna. This antenna is described as system #1 above. When one of the antenna's ten bands is tuned to the transmitter frequency, it represents a low VSWR to the transmitter. The receiver, however, may not see a low VSWR and an out-of-band mismatch loss will occur. Measurements for this loss versus frequency were made at NELC. The antenna was mounted on an extended ground plane and the out-of-band VSWR versus frequency was measured for each of the ten bands, using an HP 8407A Network Analyzer. The VSWR was converted to mismatch loss to be used in the range.

Appendix A contains a complete description of the test procedure and all curves for mismatch loss that were plotted. Some of the important results of the measurements are also given in the following section.

RESULTS

FLEET SURVEY

The operational performance requirements for the AN/VCC-2 communications system operating in the vhf band (30-76 MHz) were determined from visits to cognizant commands. No single source existed for this information; therefore, it was compiled from information supplied by all commands contacted.

The first operational requirement determined from the survey is for the VCC-2 system to have omnidirectional communication coverage in the azimuthal plane at 0° elevation for all five ship classes. This is necessary for two reasons. First, in a ship-to-ship or ship-to-shore link condition, it would not always be possible for a ship to maintain the same relative orientation with respect to another ship or shore unit. Second, the VCC-2 requires a minimum signal level during message transmission or traffic will not be received. Loss of signal results in loss of message traffic until the circuit can be reestablished. Therefore, the antenna system must provide as nearly omnidirectional coverage as possible so that the signal strength does not drop below the signal level required for proper operation of the VCC-2 system.

The second requirement is that communication be possible beyond a minimum range. The CNO specification for minimum range is 25 statute miles, which was determined in the survey of cognizant commands. This range requirement is necessary in a ship-to-shore link, for example, because of the possibility of mine fields near shore and the necessity to keep the ship out of range of shore-based ground fire during amphibious operation.

A third requirement is to keep interference levels as low as possible. This includes interference from shipboard systems as well as from off-ship sources.

A survey was conducted of as many ships having VCC-2 equipment on board as possible. Table 1 lists all ships homeported on both coasts that ever had VCC-2 installations aboard, which ships were personally visited, and the number of units now aboard, and indicates whether that ship installed its own rf distribution system.

TABLE 1. SHIPS HAVING AN/VCC-2 INSTALLATIONS.

West Coast	Visited	Units Aboard	Installed Own rf System
USS ELDORADO (LCC 11)	Yes	2	Yes
USS BLUE RIDGE (LCC 19)	Yes	3	No
USS IWO JIMA (LPH 2)	No	2	No
USS OKINAWA (LPH 3)	Yes	2	Yes
USS TRIPOLI (LPH 10)	No	2	---
USS NEW ORLEANS (LPH 11)	Yes	2	No
USS CLEVELAND (LPD 7)	Yes	2	Yes
USS DUBUQUE (LPD 8)	Yes	2	Yes
USS DENVER (LPD 9)	No	2	---
USS JUNEAU (LPD 10)	No	2	Yes
USS PAUL REVERE (LPA 248)	Yes	2	Yes
East Coast			
USS MOUNT WHITNEY (LCC 20)	Yes	3	No
USS GUADALCANAL (LPH 7)	No	2	No
USS GUAM (LPH 9)	Yes	2	Yes
USS INCHON (LPH 12)	Yes	2	No
USS LA SALLE (LPD 3)	Yes	*	*
USS CORONADO (LPD 11)	Yes	2	Yes
USS SHREVEPORT (LPD 12)	Yes	2	Yes
USS NASHVILLE (LPD 13)	Yes	2	Yes
USS CHILTON** (LPA 38)	Yes	2	Yes
USS FRANCIS MARION (LPA 249)	No	*	*
USS NEWPORT NEWS (CA 148)	Yes	2	Yes

*AN/VCC-2 units have been removed

**Decommissioning in July 1972

The ships' survey revealed that three types of antennas are presently in service for the VCC-2 system. The first, and most widely used, is the AS-1729 base-tuned, vertical, center-fed whip. The second is the AS-2231/SRA-60(V) conical dipole, and the third is the NELC-designed discone antenna. Table 2 lists only the ships visited, plus USS GUADALCANAL, by class, and shows the type and number of antennas being used for the VCC-2 and what type of ground plane is present, if any. It also shows whether a multicoupler is used or whether each antenna is hardwired to each RT-524 transceiver on a one-to-one basis. Notice that only one ship, USS GUADALCANAL (LPH 7), has discone antennas. They were installed because the AS-2231 antennas, originally required, were not yet available at the time of installation.

TABLE 2. RF DISTRIBUTION COMPONENTS FOR THE AN/VCC-2 OF SHIPS VISITED.

Ship Class/Name	Type of Antennas	Number of Antennas	Type of Ground Plane	Type of Multicouplers
LCC				
USS BLUE RIDGE	AS-2231	2	None	SRA-60(V)
USS MOUNT WHITNEY	AS-2231	2	None	Hardwired
USS ELDORADO	AS-1729	4	None	Hardwired
LPH				
USS OKINAWA	AS-1729	4	3 radials per antenna	Hardwired
USS GUADALCANAL*	Discone	3	None	SRA-60(V)
USS GUAM	AS-1729	4	None	Hardwired
USS NEW ORLEANS	AS-2231	4	None	SRA-60(V)
USS INCHON**	AS-1729	4	None	Hardwired
LPD				
USS CLEVELAND	AS-1729	4	None	Hardwired
USS DUBUQUE	AS-1729		None	Hardwired
USS CORONADO	AS-1729	4	None	Hardwired
USS SHREVEPORT	AS-1729	4	None	Hardwired
USS NASHVILLE	AS-1729	4	None	Hardwired
LPA				
USS PAUL REVERE	AS-1729	4	None	Hardwired
CA				
USS NEWPORT NEWS	AS-1729	4	None	Hardwired

*USS GUADALCANAL was not visited. Information was obtained at the Portsmouth Naval Shipyard.

**Also has AS-2231/SRA-60(V) multicoupler-antenna system aboard but it is being used for VRC-46, not VCC-2.

The only vhf multicoupler presently in shipboard service is the AN/SRA-60(V). It is an eight-drawer multicoupler which feeds two separate AS-2231 antennas.

No rf patch panels are presently being used on any ship. Two ships, however, USS NEWPORT NEWS (CA 148) and USS CORONADO (LPD 11), have indicated that they are going to build their own. They want the capability of switching any VCC-2 or VRC-46 to any AS-1729 antenna. Some ships indicated they did not desire antenna switching capability.

Figures 4-14 show the antenna arrangements on the ships surveyed. Figure 4 represents both USS BLUE RIDGE (LCC 19) and USS MOUNT WHITNEY (LCC 20). The BLUE RIDGE and the MOUNT WHITNEY have five pairs of AS-2231 conical dipole antennas, five on the port side and five on the starboard side. Each pair operates as one antenna array as they are connected by a power divider. The two pairs farthest forward on both ships are for the VCC-2.

Figures 5 through 9 show the different arrangements for LPH's. Figure 5 is for USS OKINAWA (LPH 3). Her two upper whips are the highest antennas on board. The two lower whips are too low on the superstructure. They are on either side of the stack and do not have an unobstructed view in all azimuthal directions. All four of the VCC-2 whips do have ground rods, however.

Figure 6 shows the location of the three discone antennas on USS GUADALCANAL (LPH 7). She is the only ship having this antenna. USS GUAM (LPH 9) is shown in figure 7. An hf transmitting fan antenna is also shown in this figure. When this antenna is radiating the RT-524 transceivers operating on the two lower VCC-2 whips are completely overpowered. These two AS-1729 antennas are in a very poor location. They could be mounted like the two upper whips, only forward of the mast.

Figure 8 shows USS NEW ORLEANS (LPH 11). She had the AN/SRA-60(V) rf distribution system installed in February 1972. The new antenna arrangement is as shown. She was the only ship visited which had AS-2231 dipoles mounted on the superstructure. Figure 9 is for USS INCHON (LPH 12), which shows both AS-1729 whips and AS-2231 conical dipoles on board. The whips are being used by VCC-2. The conical dipoles are used by the AN/VRC-46 radio sets.

Figure 10 shows the NEWPORT NEWS (CA 148). She is the only nonamphibious ship now using the VCC-2. Her four whips are mounted on the same level on the mast.

USS PAUL REVERE (LPA 248) is shown in figure 11. She has two whips mounted on the forward king post and two on the aft.

Figures 12-14 include the LPD class of ships. Figure 12 shows USS CLEVELAND (LPD 7) with her four whips on the 07 level of the mast, mounted on the ends of four equal-length supports forming a square. It is a good installation. USS DUBUQUE (LPD 8) (fig. 13) has her aft whips mounted as on the CLEVELAND; however, the other two whips are mounted higher, fore and aft on a yardarm. USS CORONADO (LPD 11), USS SHREVEPORT (LPD 12), and USS NASHVILLE (LPD 13) all have very similar installations as shown in figure 14. They are very high on the mast and have little obstruction.

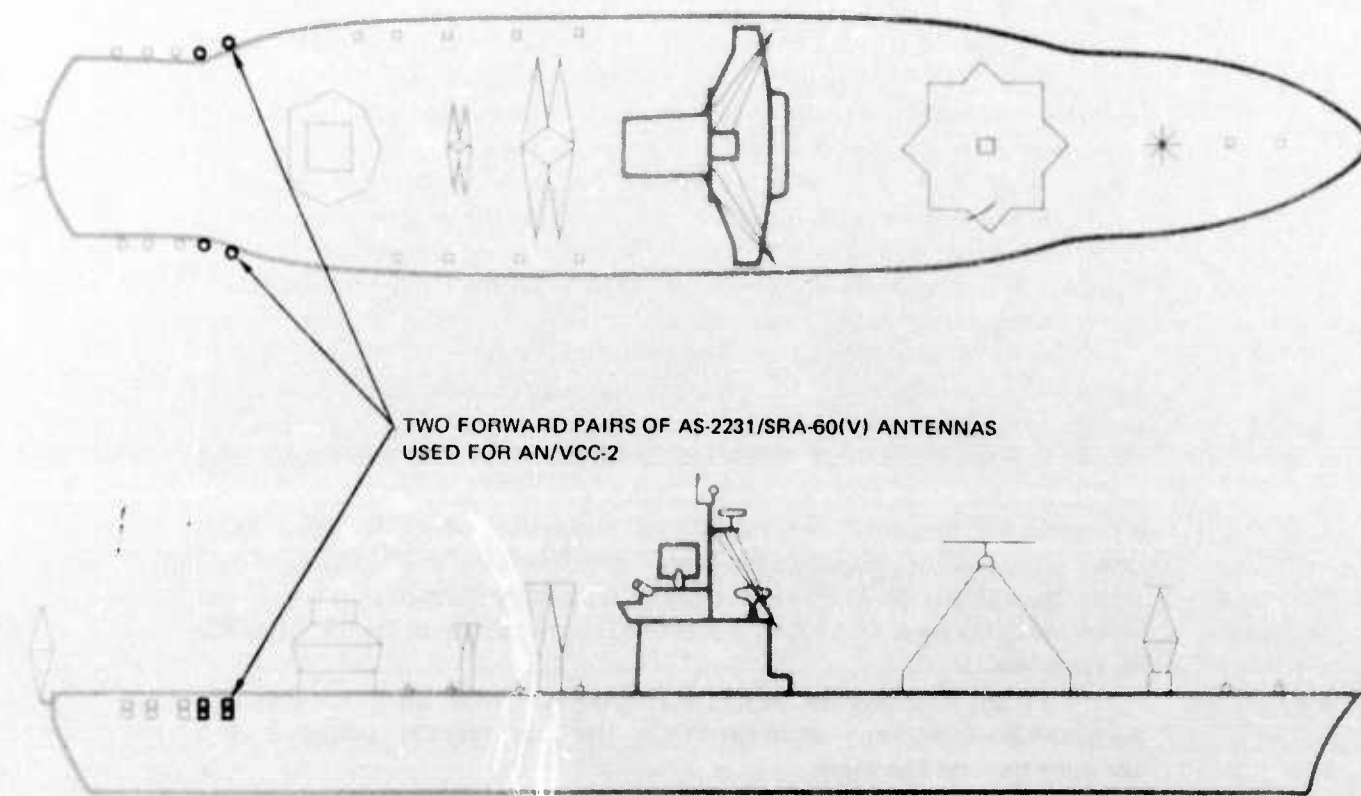


Figure 4. Antenna arrangements on USS MOUNT WHITNEY (LCC 20) and USS BLUE RIDGE (LCC 19).

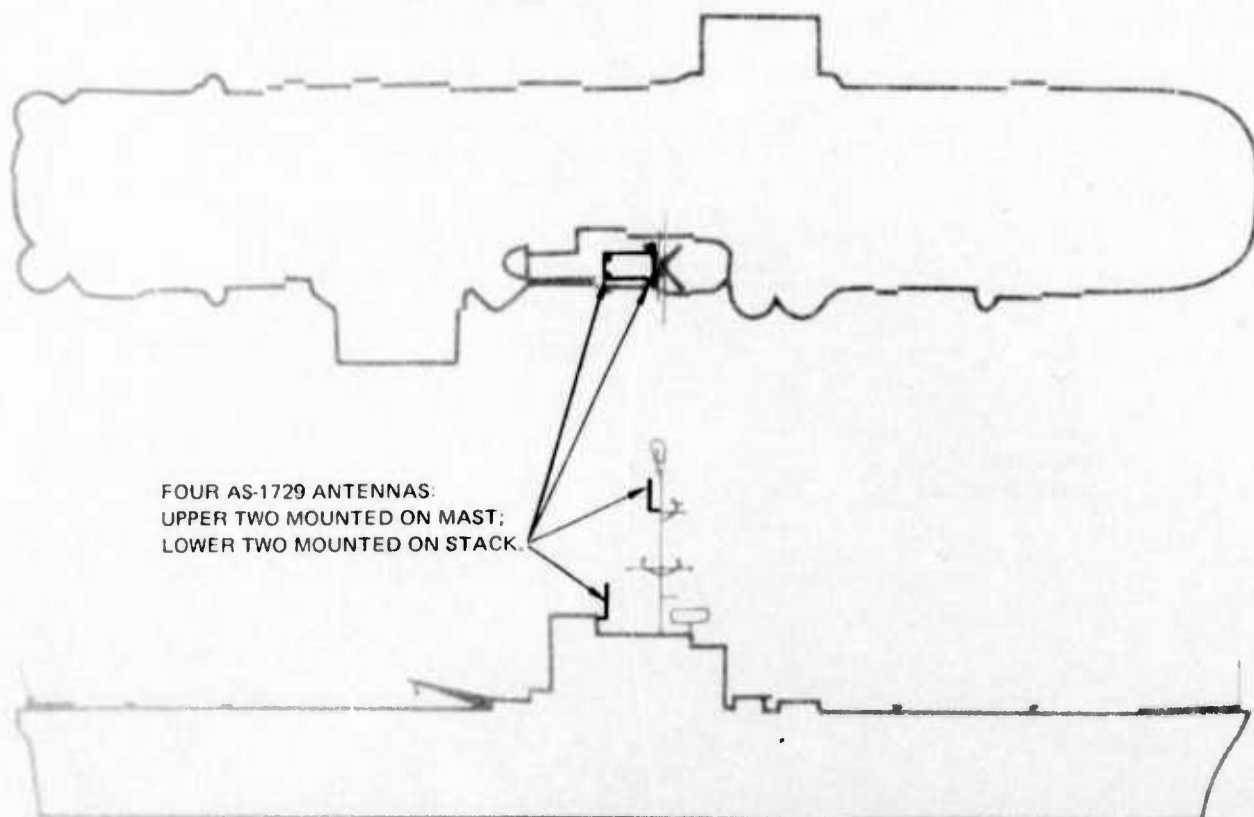


Figure 5. Antenna arrangement on USS OKINAWA (LPH 3).

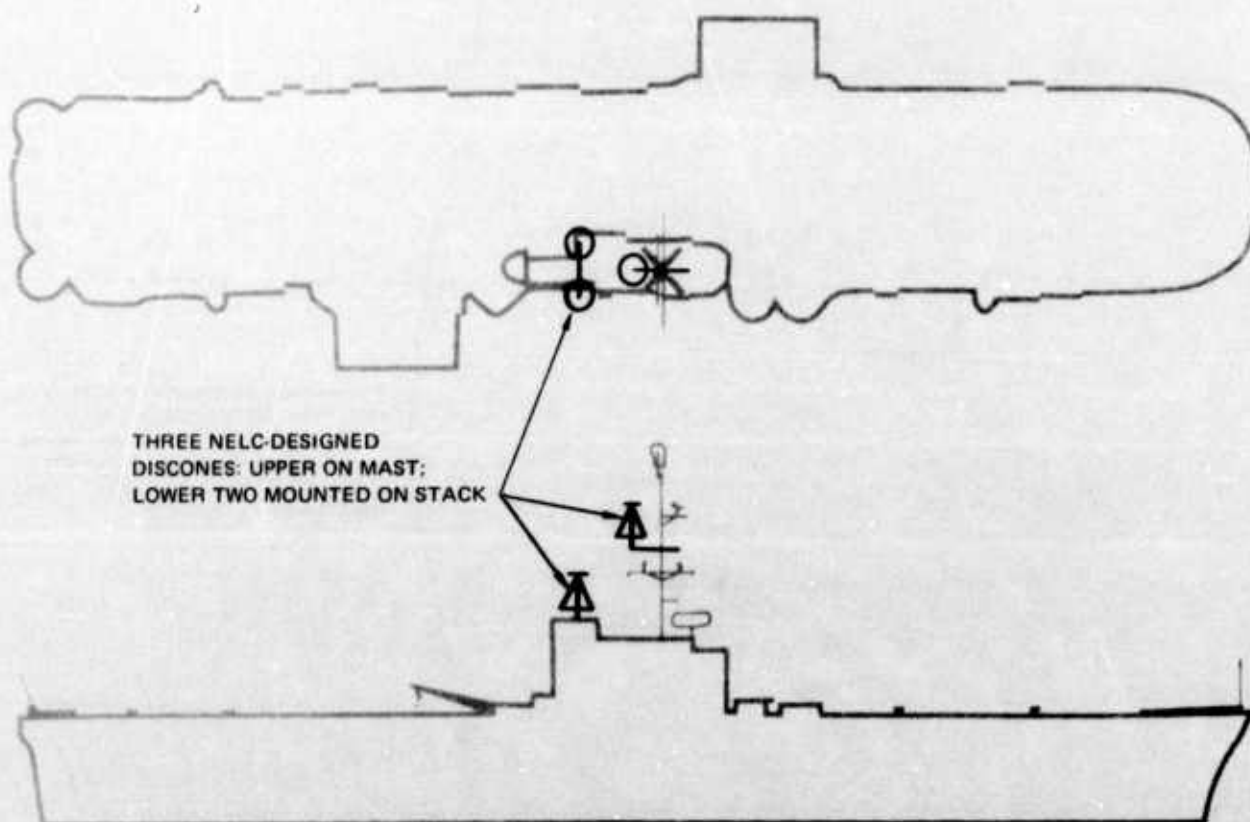


Figure 6. Antenna arrangement on USS GUADALCANAL (LPH 7).

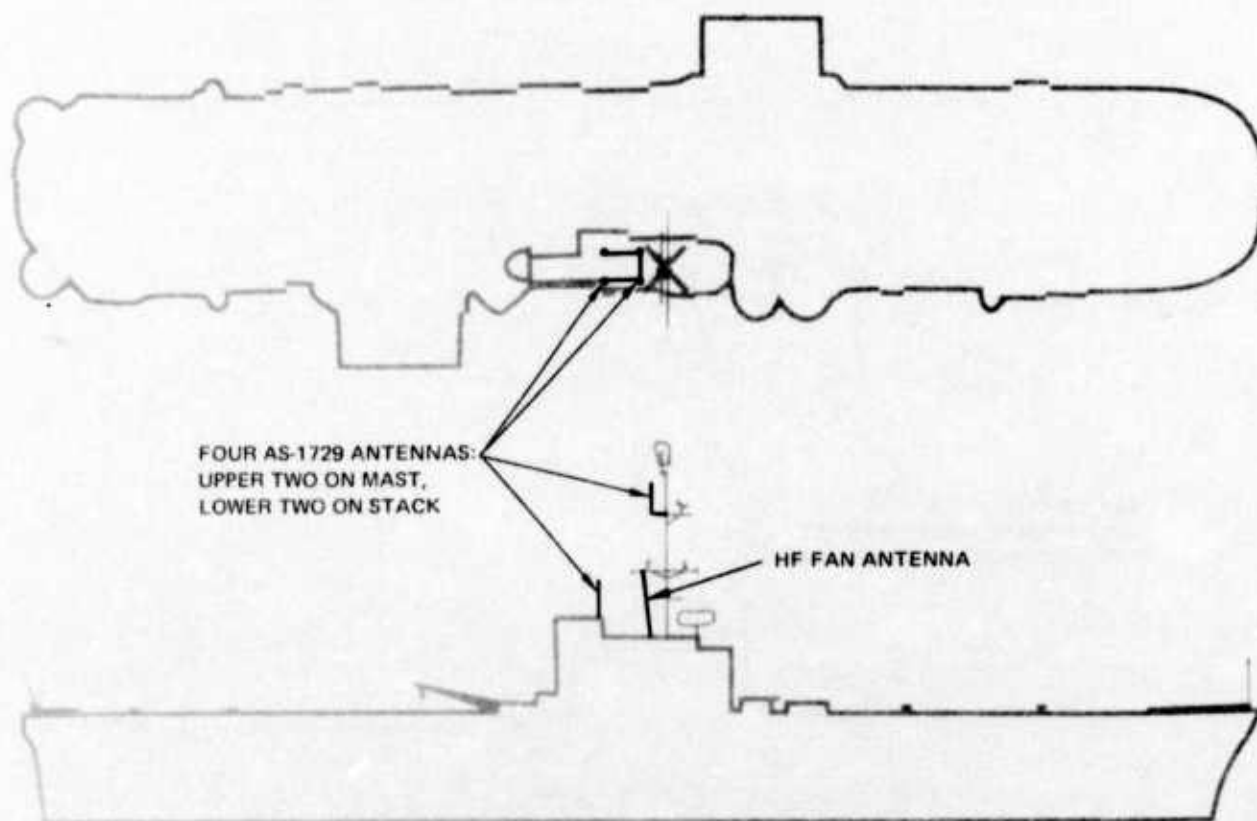


Figure 7. Antenna arrangement on USS GUAM (LPH 9).

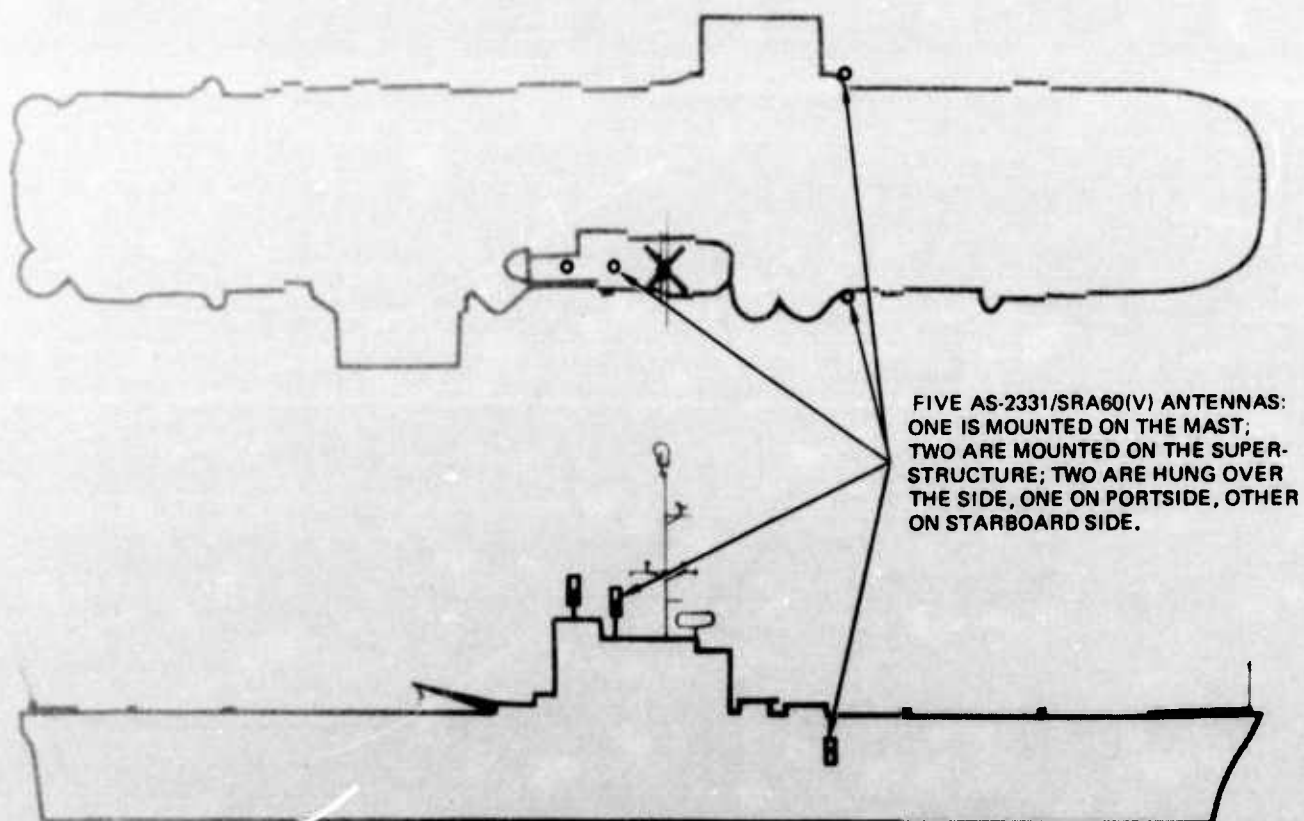


Figure 8. Antenna arrangement on USS NEW ORLEANS (LPH 11).

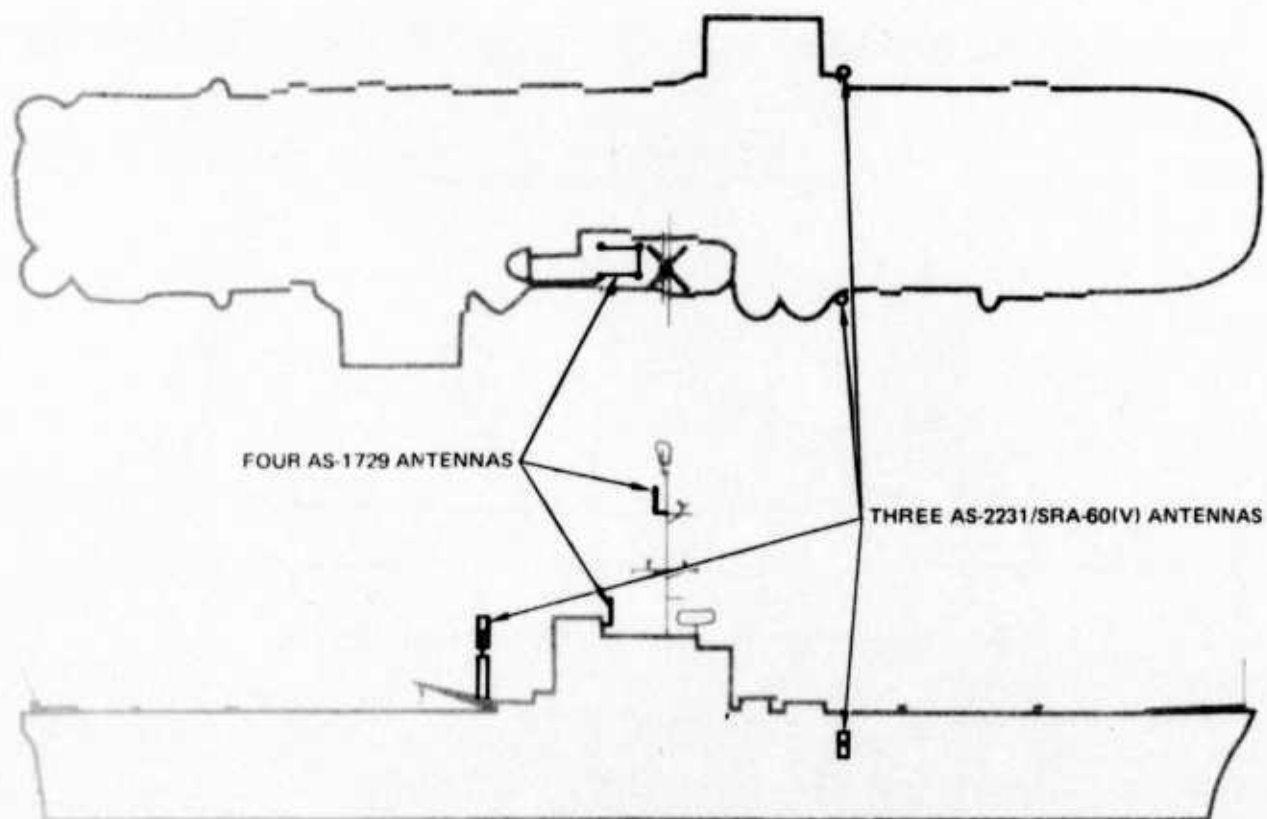


Figure 9. Antenna arrangement on USS INCHON (LPH 12).

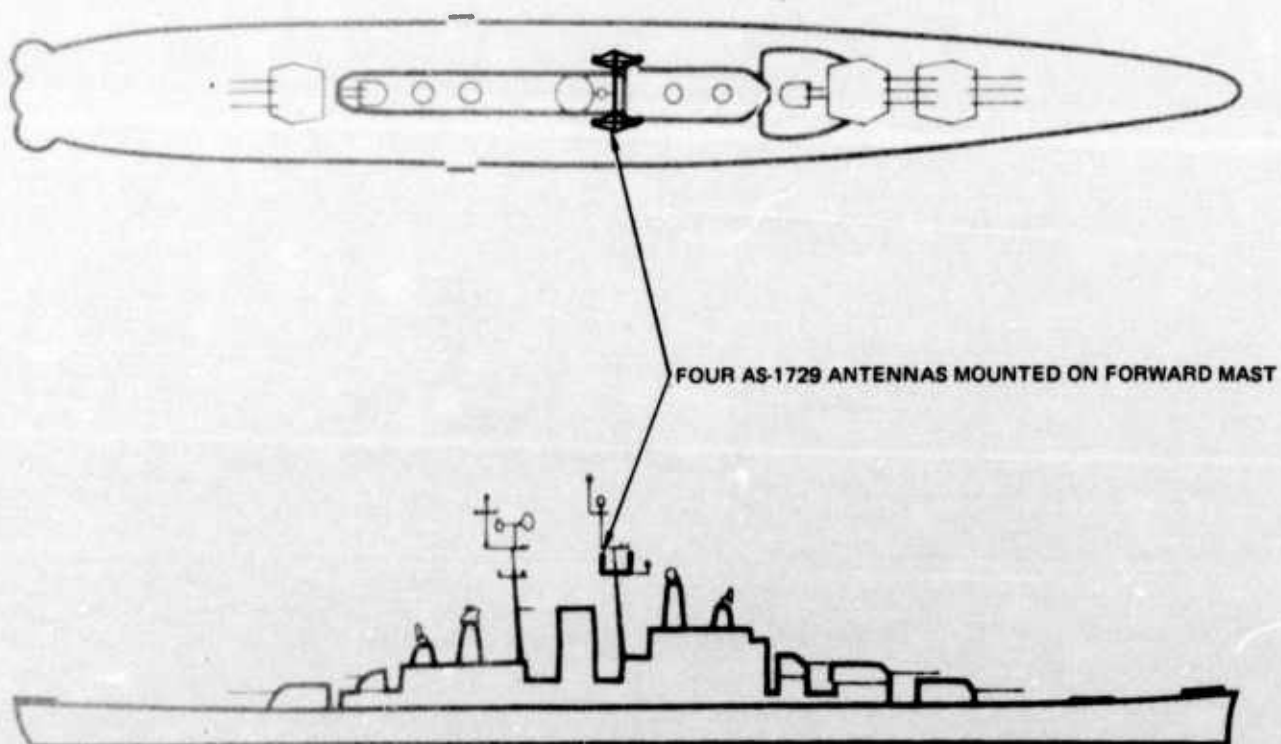


Figure 10. Antenna arrangement on USS NEWPORT NEWS (CA 148).

A PORT AND A STARBOARD AS-1729 ANTENNA IS MOUNTED ON BOTH THE FORE AND AFT KING POSTS

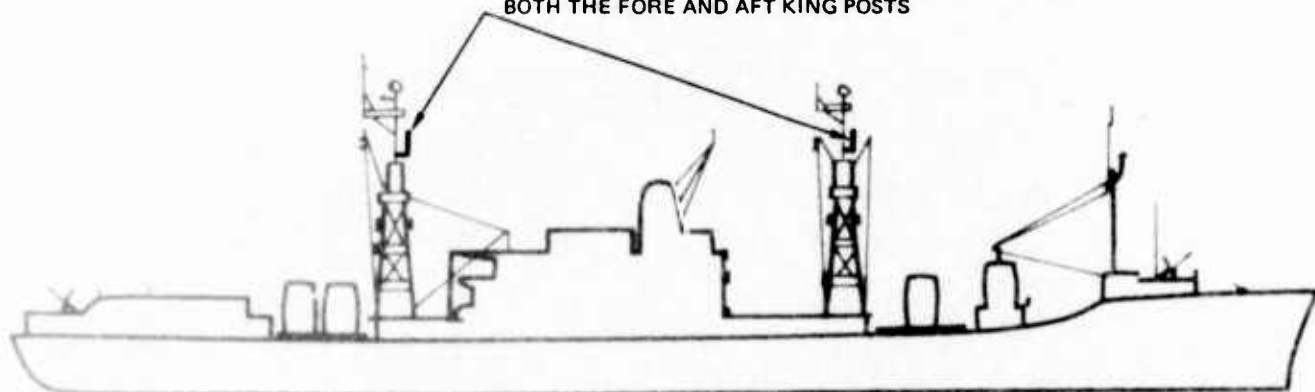


Figure 11. Antenna arrangement on USS PAUL REVERE (LPA 248).

FOUR AS-1729 ANTENNAS MOUNTED IN AN "X" CONFIGURATION AT EQUAL LEVEL

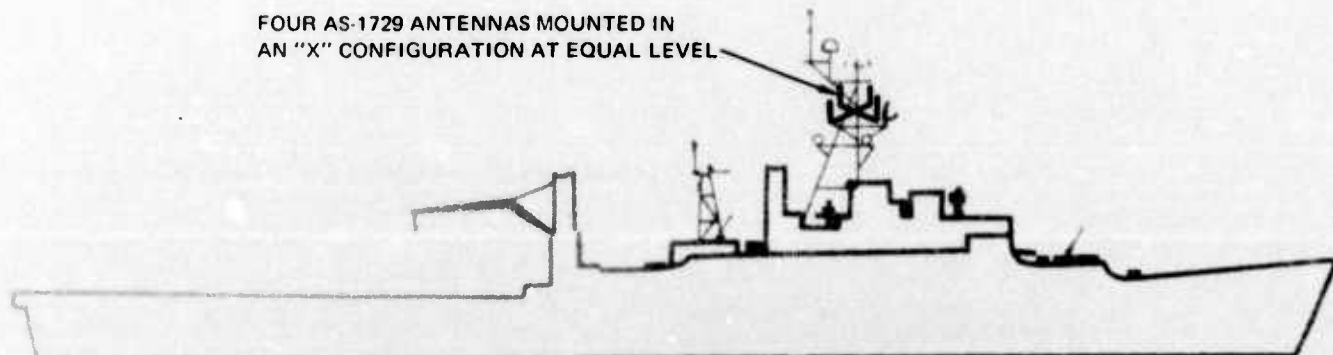


Figure 12. Antenna arrangement on USS CLEVELAND (LPD 7).

FOUR AS-1729 ANTENNAS: THE UPPER TWO ARE MOUNTED FORE AND AFT AT ONE LEVEL; THE LOWER TWO ARE MOUNTED IN A "V" CONFIGURATION

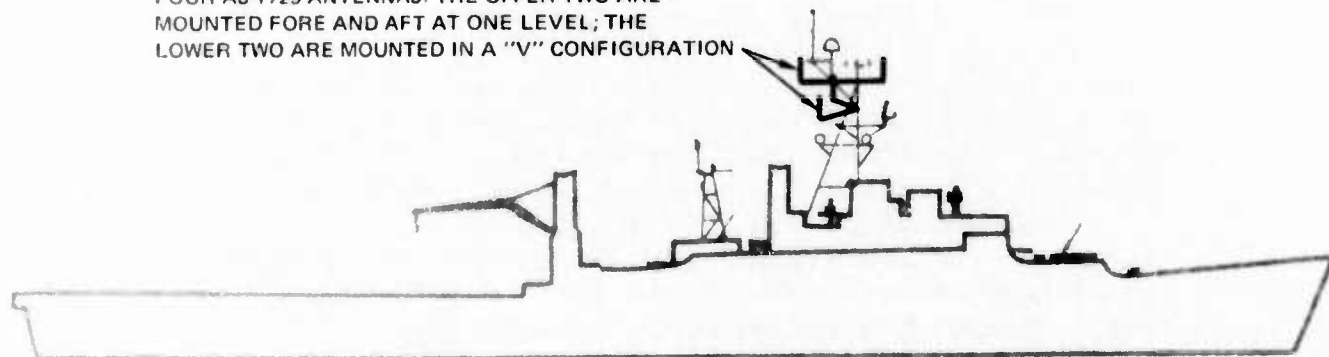


Figure 13. Antenna arrangement on USS DUBUQUE (LPD 8).

FOUR AS-1729 ANTENNAS MOUNTED AN EQUAL DISTANCE FROM THE MAST AT THE SAME LEVEL, FORE AND AFT, PORT AND STARBOARD

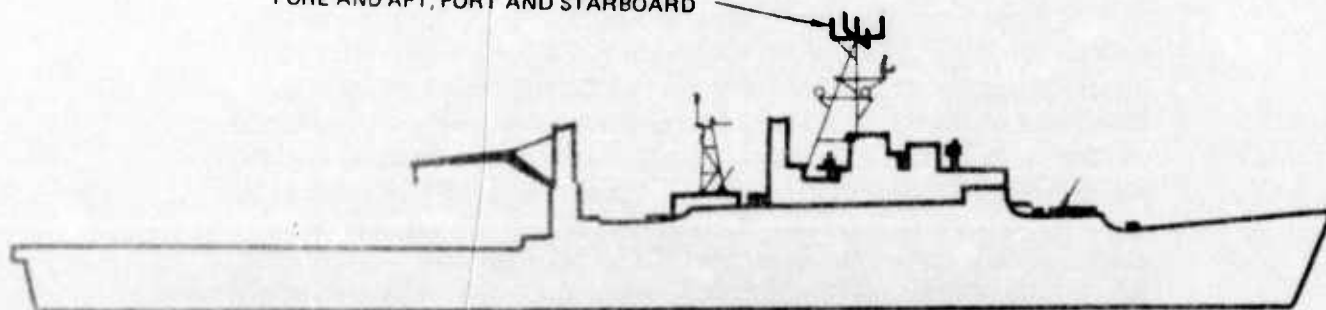


Figure 14. Antenna arrangement on USS CORONADO (LPD 11), USS SHREVEPORT (LPD 12), and USS NASHVILLE (LPD 13).

From the above, it is evident that antenna placement did not follow a general guidance plan. For some ships, finding a relatively good location was a simple task; for others, the only places available were less desirable.

The AS-1729 whip antenna is base tuned. The base is constructed such that moisture is able to leak into it and short out some of the tuning bands. Most of the ships having this antenna have used a silicon compound to better seal the metal-to-metal joints. Not all ships have done this yet and are, consequently, still having this problem. NELC has designed a box on which this antenna can be mounted. The box serves to protect both the tuning base and the rf and tuning cable connections in the bottom of the base, and also relieves any cable strain on these connections due to the weight of the cable.

Many of the ships visited were experiencing nulls somewhere in their coverage. A preliminary investigation of the antenna patterns for eight ships indicates that some serious nulls are present. The effect of these nulls on range performance in a communication link is discussed later.

The survey indicated that most ships have communicated with other ships or beach units only under conditions of a nearly constant relative orientation towards each other and only for ranges of 10 miles or less. Those ships which have communicated for all orientations have experienced loss of signal due to antenna pattern nulls. For instance, USS MOUNT WHITNEY (LCC 20) has a deep null about 15° wide in the forward direction that limits any VCC-2 transmission or reception in that direction.

A few ships have used their VCC-2 as a relay between a ship-to-ship and/or ship-to-shore link. This provides a greater range capability and overall system versatility between VCC-2 installations.

Some ships reported having interference problems that reduce their performance reliability. USS BLUE RIDGE (LCC 19) reported fading at ranges of 18 miles and others, such as USS NEWPORT NEWS (CA 148), have had modulation problems when operating their VRC-46 transceivers simultaneously with the VCC-2 transceivers. The MOUNT WHITNEY (LCC 20) has locally generated static problems and the OKINAWA (LPH 3) loses communication contact during helicopter operations near the ship.

Table 3 lists the relative performance characteristics of the ships visited. The ranges listed are not always the maximum range possible, but rather the range over which the ship has had the opportunity to communicate. Directivity of the ship's antenna patterns is a relative indication based solely on comments by ship's personnel. "Quality" is a relative rating of one ship's performance with respect to the others. Again, it is based on comments by ship's personnel and is not intended as a criticism or endorsement of a particular installation. The term "good" does not necessarily imply that the ship is fully meeting her operational requirements, but only that she is meeting them in a better than average manner.

USS MOUNT WHITNEY had experienced ability to communicate with a helicopter approximately 15 miles distant, but was unable to communicate with a ship only 12 miles away. The MOUNT WHITNEY uses AS-2231/SRA-60(V) antennas suspended vertically over the sides in the after-quarter of the ship (see fig. 4). It is not known whether their problem was vertical radiation patterns or equipment problems. More information is required.

**TABLE 3. RELATIVE PERFORMANCE OF THE
AN/VCC-2 ONBOARD SHIPS SURVEYED.***

Ship Class/Name	Range (mi)	Antenna Directivity	Interference	Communication Quality
LCC				
USS BLUE RIDGE	20**	Nearly omni-directional	Experienced some fading	Good
USS MOUNT WHITNEY	10-15	Deep null forward of approx. 15°	Ship roll creates static	Fair
USS ELDORADO	10-15	Has nulls	—	Poor
LPH				
USS OKINAWA	20 max	—	Due to helicopters	Fair
USS GUAM	5-10	—	—	Fair
USS NEW ORLEANS	Presently changing systems in shipyard			
USS INCHON	5-10	Has nulls	—	Poor
LPD				
USS LA SALLE	VCC-2's have been removed			
USS CLEVELAND	7-10	Nearly omni-directional	—	Fair
USS DUBUQUE	10-15	Nearly omni-directional	—	Good
USS CORONADO	1-8	Nearly omni-directional	—	Poor
USS SHREVEPORT	5	Nearly omni-directional	—	Good
USS NASHVILLE	Has not used VCC-2 enough to comment			
LPA				
USS CHILTON	Decommissioned in July 1972			
USS PAUL REVERE	Has not used VCC-2 operationally			
CA				
USS NEWPORT NEWS	5-10	Nearly omni-directional	Cross modulation	Poor

*All information in this table is based on comments made by ship's personnel during survey.

**Claims a 48-mile range on a ship-to-shore link.

OUT-OF-BAND VSWR OF AS-1729 ANTENNA

Measurements were made at NELC of the out-of-band mismatch loss to a 50-ohm system for the AS-1729 antenna (see Appendix A). The HP 8407A Network Analyzer was used to measure the return loss and an X-Y recorder was calibrated in VSWR versus frequency to record the plots. The antenna was mounted on an extended ground plane and had a measured in-band VSWR of 3.75:1 or less. Band 1 (30-33 MHz) falls below a 2:1 VSWR at 30 to 32 MHz and at 68 to 76 MHz. Band 4 (37-42 MHz) falls below 2:1 from 37 to 40.5 MHz and also band 5 (33-37 MHz) from 32 to 37 MHz and again at 71.5 to 73.5 MHz. Band 6 (53-56 MHz) falls below 2:1 from 52 to 53 MHz. When the antenna is mounted on an extended ground plane, the VSWR is within 3:1 except for band 7 (65 to 70.5 MHz), band 9 (60 to 65 MHz), and the upper one-third of band 10 (56-60 MHz). If the antenna were mounted in an elevated location without a ground plane (no counterpoise) these VSWR's would change. In order to control the possible impedance variations due to various mounting locations, all AS-1729 antennas should be installed with a counterpoise consisting of eight 54-inch radial rods.

Plots of VSWR versus frequency for all ten bands are given in Appendix A. In these plots, a general trend appears. The highest VSWR's appear at frequencies below the tuned band and lower VSWR's appear at frequencies above the tuned band. Assuming that the proper band is selected for the transmitting frequency, f_t , then the range of maximum out-of-band mismatch loss for receive frequencies below the band, f_r , is 8.3 to 10 dB (2.5 to 3.8:1 VSWR), and for receive frequencies above the band, f_r , is 1.4 to 4 dB (2.9 to 10.1 VSWR) in the 30 to 76 MHz range. This gives a maximum mismatch loss of 4 dB for f_r above f_t and 10 dB for f_r below f_t .

RF SYSTEMS ANALYSIS

Each of the seven antenna and rf distribution system approaches is analyzed in terms of maximum predicted range performance. Restrictions in antenna pattern coverage apply to all systems. A null in an antenna's radiation pattern will cause a degradation in the system's range performance, on the order of 1 mile loss in range per dB of null depth. This is true for any of the antennas considered. For some systems, electrical or mechanical advantages and disadvantages, circuit adaptability, and performance reliability aspects are discussed.

The range prediction curves of figures 3A-G are for 28 ship-to-ship/shore combinations that could exist with the seven system approaches. Each of the 28 possibilities will be referred to in this analysis by its combination number, and each of the seven approaches by its system number. The ranges plotted represent the maximum range over which a two-way communication link between VCC-2 units could be utilized. That is, the range is limited to the worst case of either the transmit or receive side of the duplex circuit (when they are different); under certain conditions, greater ranges might be achieved in a one-way circuit. Certain simplifying assumptions apply to the curves. They

are plotted for ideal antenna radiation patterns with respect to a quarterwave monopole. Any null in an actual shipboard antenna can decrease the range by approximately 1 mile per dB of null depth. Add to this the null depth of the antenna of the other ship or shore unit, and one finds that the range can decrease rapidly just on the basis of pattern nulls. Range can also be decreased by any other factor that introduces attenuation into the circuit such as poor electrical contacts, higher VSWR's than designed for, or the RT-524 transceiver not transmitting at least 40 watts. Analysis of each of the seven system approaches (illustrated in fig. 1) follows.

1. System #1 was described in the section entitled "Individual Shipboard Systems." It consists of two AS-1729 antennas per VCC-2 unit. Two VCC-2 units (four RT-524 transceivers) per ship is the most common configuration (some have three) for a requirement of at least four separate AS-1729 antennas. In system #1 the ship must then find suitable locations for four antennas and place them high enough and space them widely enough to provide omnidirectional coverage. No ship using this system was able to isolate each AS-1729 from another by 30 feet or more (some by only 10 feet or less) and this can result in mutual pattern distortions adversely affecting range. Figure 3A indicates the maximum range attainable between a ship-to-ship/shore link terminated at each end by system #1. This is combination #1 and shows a range of 66 miles at 30 MHz decreasing to 21 miles at 76 MHz. With the exception of combination #13, this is the best range performance of all the identical system combinations. However, the need to suitably mount and maintain four identical antennas can offset this range advantage. The maximum range (using system #1) occurs when system #1 is terminated with system #4, combination #4 in figure 3A. The range variation is 66 miles at 30 MHz, decreasing to 22 miles at 76 MHz. All other terminations with system #1 will result in shorter range capability. However, a 10-dB antenna pattern null will result in a loss in range of at least 10 miles and, assuming a pattern null of equal depth on the other ship, a net loss of 20 miles can occur. The other combinations using system #1 are 2, 3, 20, 23, and 26 of figures 3A, E, F, and G.

The AS-1729 antenna was originally designed for vehicular use and has a spring mount. There is no electrically equivalent antenna available in the Navy equipment inventory that is specifically designed for use in the shipboard environment. This spring mount is subject to corrosive forces and fatiguing shipboard vibrations that can cause it to break. As such, it becomes a hazard to equipment and personnel and can cause the loss of a communications channel. When the AS-1729 is used in shipboard service, this spring should be replaced with a rigid section. A suitable rigid section has been designed by the Naval Electronics Laboratory Center and is described in a NAVSHIPS publication.³

2. System #2 is composed of one AS-1729 antenna in place of the two required in system #1, and the REP CU-1857/TRC diplexer. The diplexer uses two notch filters to allow one antenna to be used simultaneously for both receive and transmit on different frequencies. This reduces by one-half the

³NAVSHIPS 0967 177 3030, *Shipboard Antenna Systems*, vol. 3, p. 6-73; 6-77.

number of antennas required per VCC-2 unit, which in turn reduces by one-half the number of locations needed aboard a ship for antenna mounting. If half as many locations are necessary, the opportunity to find the best locations has increased and the antenna's separation from other antennas and/or superstructures is improved. The requirement for fewer antennas increases the availability of spaces where an antenna will have an unobstructed 360° view with fewer and smaller pattern nulls. Thus the ideal antenna assumed in the range's curves can be more closely approximated.

Whenever the AS-1729 is used in conjunction with the CU-1857 diplexer, the out-of-band mismatch loss of the antenna must be considered, since the diplexer allows for receiving on a frequency that is not within the antenna band selected for the transmitting frequency. As stated under "Out-of-Band VSWR of AS-1729 Antenna," the maximum mismatch loss for receive frequencies f_r , below the transmit frequency, f_t , is 10 dB and for frequencies f_r above f_t the mismatch loss is 4 dB. Because of this condition, for two mismatch losses, the range curves for system combinations using system #2 are plotted as two separate curves. Curves 2, 5, 6, 7, 8, 24, and 27 of figures 3A, B, F, and G are plotted for the two cases: $f_r < f_t$ (10 dB mismatch loss) and $f_t < f_r$ (4 dB mismatch loss).

Combination #5 in figure 3B shows a maximum range variation of 55 (43) miles at 30 MHz, decreasing to 15 (11) miles at 76 MHz for $f_t < f_r$ ($f_r < f_t$). The maximum range attainable with system #2 is when terminating with system #4, which is combination #7. The range variation is 57 (46) miles at 30 MHz to 17 (13) miles at 76 MHz for $f_t < f_r$ ($f_r < f_t$). All other combinations have shorter range capabilities. The decrease in range of combination #2 from combination #1 is on the average about 10 miles for $f_t < f_r$ across the band. This is due to the insertion loss of the diplexer. The expense of 10 miles loss in range is the cost of reducing the antenna requirement by half.

3. System #3 consists of the discone antenna designed by the Naval Electronics Laboratory Center and built by Norfolk Naval Shipyard and the AN/SRA-60(V) built by DECO. The discone has not undergone any extensive technical evaluation as of this date, nor has it undergone any shock and vibration analysis. Preliminary VSWR measurements were performed by the Portsmouth Naval Shipyard to determine its capability with the VCC-2 system. It has been installed only aboard USS GUADALCANAL, and performance information for this report has been unavailable because of her deployment. The design of the discone offers a potential for greater structural rigidity than the AS-2231 conical dipole of system #4. The discone is compatible with the SRA-60 antenna coupler. Figure 3C shows maximum range prediction for ship-to-ship/shore combination #9 of discone and SRA-60 to discone and SRA-60 communications link. Expected range is 55 miles at 30 MHz decreasing to 17 miles at 76 MHz. Again, this is for an ideal antenna not having radiation pattern nulls. Range will decrease at approximately 1 mile per dB of pattern null. System #3 is included in combinations 3, 6, 9, 10, 11, 12, and 28 of figures 3A, B, C, and G. Its termination with system #4, combination #10, has the greatest range prediction. This is approximately 4 miles greater range, on the average, than can be expected with the discone-to-discone combination.

4. System #4 consists of DECO's AS-2231/SRA-60(V) antenna and AN/SRA-60(V) Antenna Coupler Group. This system, as indicated in table 2, is presently being used aboard three ships for the VCC-2. USS INCHON uses AS-2231 antennas for the VRC-46. The AS-2231 is 13 feet in height, 4 feet in diameter, and weighs 400 pounds. Because of this large size and design, it is susceptible to fatiguing shipboard vibrations that have caused elements on the antenna to break. Mounting locations are also a problem with this large antenna. Four ships, USS BLUE RIDGE, USS INCHON, USS MOUNT WHITNEY, and USS NEW ORLEANS, have mounted these antennas over the sides which has resulted in some being damaged by wave action. An omnidirectional antenna mounted over the side is completely obstructed by the ship from one side. A second antenna must then be mounted on the opposite side and connected to the first by a power divider to give complete omnidirectional coverage. The AS-2231 antenna has been used in this manner and has resulted in doubling the antenna requirement.

Combination #13 shown in figure 3D shows that the range variation for the identical system #4 ship-to-ship/shore combination is 66 miles at 30 MHz decreasing to 22 miles at 76 MHz. This combination provides the maximum range prediction of system #4 combinations as well as all other combinations.

Other combinations involving system #4 are 4, 7, 10, 14, 15, and 16 of figures 3A, B, C, and D.

5. System #5 consists of Radio Engineering Products (REP) F62420 whip antenna and F64685 antenna coupler. System #5 operates with the coupler in its dual four-port mode, which allows for two VCC-2 units to be operating into a single broadband antenna. Two VCC-2 units would normally require four separate antennas, so an antenna reduction of three is possible. However, use of the coupler adds insertion loss into the system (table B-2), which reduces the maximum range since range is proportional to available power output.

Figure 3E shows the range plot for the identical system ship-to-ship/shore combination #17. The range variation is a maximum of 12 miles at 40 MHz and a minimum of 6 miles at 30 MHz. This system combination shows a definite range reduction due to the antenna multicoupler insertion loss and antenna gain. This system achieves its maximum range when terminated by system #4 as shown in figure 3D, combination #14. The maximum range variation is 27 miles at 40 MHz and 12.5 miles at 76 MHz. The other combinations using system #5 are 8, 11, 18, 19, and 20 in figures 3B, C, and E.

6. System #6 consists of the REP F62420 whip antenna and the F64685 antenna coupler, but with the coupler in the eight-port mode. The eight-port mode would accommodate four VCC-2 units into one antenna for an antenna reduction of seven, but has a higher insertion loss in this mode than in the dual four-port mode. This higher insertion loss is reflected in the decrease in predicted range across the band. Combination #21 of figure 3F shows the range variation of identical system #6 ship-to-ship/shore terminations. The maximum is 9 miles at 70 MHz and the minimum is 3 miles at 30 MHz. A decrease in range performance of approximately 3 miles on the average across the band occurs over the performance of combination #17, identical

dual four-port modes. The greatest range attainable with system #6 is when system #4 is the other termination. This is combination #15 of figure 3D. The range variation is from 23 miles at 40 MHz to 11 miles at 76 MHz. The other system #6 combinations are 12, 18, 22, 23, and 24 of figures 3C, E, and F.

7. System #7 consists of the REP F62420 antenna and the REP CU 1857/TRC diplexer. This is basically the same system as system #2 with the AS-1729 antenna being replaced by the F62420 antenna. The AS-1729 antenna is a tuned antenna, but the F62420 is a broadband so a mismatch loss term is not included separately. The range curves for systems terminating with system #7 are combinations 16, 19, 22, 25, 26, 27, and 28 of figures 3D, E, F, and G. The identical system #7 ship-to-ship/shore combination #25 of figure 3G shows a range variation of 21 miles at 40 and 70 MHz to 12 miles at 30 MHz. The maximum range attainable with system #7 is when it is communicating with system #4. This is combination #16 of figure 3D. The range variation is a maximum of 34 miles at 40 MHz to a minimum of 16 miles at 76 MHz.

BEST SYSTEM APPROACH

From the analysis of the seven VCC-2 antenna and rf distribution system approaches, system #2 emerges as the best approach. Its first major advantage is that it cuts the antenna requirements in half because of the CU-1857 diplexer. Only half as many antennas need to be mounted and maintained as in system #1. Its AS-1729 antennas are not as large or as subject to fatiguing vibrations as are the discone and AS-2231 antennas of systems #3 and #4. The notch filter diplexer is a more reliable, acceptable equipment than the F64685 multicoupler. Tests made on the F64685 multicoupler and F62420 antenna by the Naval Electronics Laboratory Center have shown their performance to be unacceptable for shipboard service in their present design condition.

Figure 1 shows two RT-524 transceivers using only one AS-1729 antenna. The diplexer, in requiring only one antenna for two transceivers, provides a second advantage. The use of one antenna provides the same antenna radiation pattern for both the transmitting and receiving transceivers. Therefore, if one side of the duplex circuit is able to transmit successfully to another system, it should also be able to receive from that other system (assuming the other system uses the same antenna for receive and transmit).

The predicted range that can be expected with an identical system #2 combination is not the maximum range that can be achieved by any other identical system combination. Identical system #4 combination #13 (fig. 3D), for example, has an average range improvement across the 30 to 76 MHz band of 10 miles for the case of $f_t < f_r$ and 14 miles when $f_r > f_t$. However, this range performance improvement is not of sufficient magnitude to offset some of the disadvantages of system #4. The range variation of combination #5 is 55 (43) miles at 30 MHz, decreasing to 15 (11) miles at 76 MHz for $f_t < f_r$ ($f_r < f_t$). The range requirement for the VCC-2 system is 20 to 25 miles

which combination #5 fails to meet above 55 MHz for $f_t < f_r$ and 45 MHz for $f_r < f_t$. This is a disadvantage; however, only combinations involving systems #3 or #4 have an improved range performance and these two systems have offsetting disadvantages. The size of the AS-2231 antenna of system #3 or the discone of system #4 is a major problem. As stated earlier, these large antennas in most cases must be hung over the sides of a ship, which involves the need for two antennas to perform the requirements of one. This doubles the cost, maintenance, and reliability problems. These large antennas are exposed to shipboard vibrations that have been causing the elements to break. Further, the SRA-60 antenna coupler is a complicated piece of equipment presenting a greater likelihood of failure than the simpler, smaller diplexer unit. These considerations rate system #2 as the most desirable for a VCC-2 rf distribution approach.

To extend the capability of this approach a patch panel (none now exists in the Navy inventory) should be included as part of the system. This panel would provide two major functional improvements. Firstly, it would enable VCC-2 radio sets to be patched to different multicouplers as a means of increasing circuit adaptability. Should a multicoupler, diplexer, or RT-524 transceiver fail, a patch panel would allow the faulty unit to be replaced in the circuit. Secondly, a patch panel would allow a particular antenna to be utilized if it were determined that its characteristics were better suited to a particular communication link.

An antenna could be mounted so that it would have a large null in the port direction, and if the operator attempted a link with another ship off his port side, he could easily patch another available antenna with a more favorable radiation pattern.

ALTERNATE SYSTEM APPROACHES

As stated above, system #2, which uses the AS-1729 pretuned whip antenna in conjunction with the CU-1857 diplexer, evolves as the best approach. However, two other systems emerge of almost equal rank. System #3, which uses the AS-2231 conical dipole with the SRA-60 antenna coupler, and system #4, which uses the discone antenna with the SRA-60, rank about equal in overall preference. The first major advantage to either of these systems is the predicted range performance attainable. Combination #13 (fig. 3D), which uses system #4 at each end, has the maximum range of any of the seven combinations that use identical systems. The range variation is 66 miles at 30 MHz, decreasing to 21 miles at 76 MHz. Combination #9 (fig. 3C), composed of system #3 at each end, has a range variation of 55 miles at 30 MHz to 17 miles at 76 MHz. So, two ships each having system #4 aboard could communicate at the greatest range, and each with system #3 aboard could communicate at the next greatest range. Also, all other systems achieve their maximum ranges when terminating with system #4 and next greatest range when terminating with system #3.

These two systems could turn out to be the best system approaches if the AN/SRA-60 could be made an eight-channel multicoupler in place of

the present four channels and if a more reliable antenna were designed. This would halve the antenna requirement and increase system reliability.

CONCLUSIONS

The following conclusions for the AN/VCC-2 antenna and rf distribution system approaches have resulted from visits to cognizant commands and from the predicted range and system analyses.

OPERATIONAL FINDINGS

1. The AN/VCC-2 should be able to communicate to a minimum of 25 statute miles for both ship-to-ship and ship-to-shore links.
2. The VCC-2 system should have omnidirectional antenna radiation pattern coverage.
3. The VCC-2 is needed as a relay to extend the range between ship-to-ship and ship-to-shore vhf links.
4. The VCC-2 should not be subjected to avoidable interference or attenuation in the system that could cause it to lose its required signal-to-noise ratio.
5. Only system #3, the NELC-designed discone antenna and AN/SRA-60 (V) Antenna Coupler Group; and system #4, the AS-2231 antenna and AN/SRA-60(V) Antenna Coupler Group, are able to meet or exceed the minimum range requirements across the 30-76 MHz band when used in an identical ship-to-ship/shore combination.
6. System #2, the AS-1729 antenna and CU-1857 diplexer, is the optimum rf distribution approach for the VCC-2 system with presently available equipment.
7. Systems #3 and #4 are the best alternate antenna and rf distribution approaches.

PHYSICAL FINDINGS

1. Most of the AS-1729 antennas do not have ground rods.
2. Tuning bases in the AS-1729 antenna are subject to moisture leakage.
3. AS-1729 antennas mounted on the stacks of LPH's do not have completely unobstructed views in the horizontal plane.
4. Most ships do not have multicouplers.
5. No ships have rf patch panels.
6. Three different rf systems are presently in service for the VCC-2.

OPERATIONAL PROBLEMS

1. No ship is fully able to meet the operational requirements described in this report.
2. Some ships have not used the VCC-2 equipment enough to establish a performance record.
3. Many deep nulls exist in the present antenna patterns.
4. The SRA-60(V) antennas on USS MOUNT WHITNEY have approximately a 15° null in the forward direction.
5. Some ships are experiencing interference problems such as intermodulation, cross-modulation, fading, local static, and interference due to nearby helicopters.

RECOMMENDATIONS

The following recommendations are based on the information obtained from the survey and analyses of the AN/VCC-2 antenna and rf distribution approaches.

1. A patching panel capability should be provided to increase the rf distribution circuit adaptability.
2. A simple diagnostic system should be provided to enable the operator to determine whether the VCC-2 is radiating. This system could be a power meter connected to the antenna lead-in cable or a vhf monitor receiver.
3. The AN/SRA-60(V) Antenna Coupler Group should be redesigned to extend its capability from four to eight channels per antenna.
4. The REP CU-1857/TRC diplexer should be used in conjunction with the AS-1729/VRC antenna, system #2, to reduce the antenna requirement and increase the pattern coverage capability.
5. The AS-2231/SRA-60(V) and the NELC discone antennas should be structurally strengthened because of their high incidence of breaking under the stress of fatiguing shipboard vibrations.
6. A counterpoise of 54-inch radial rods should be installed for all AS-1729 antennas.
7. All AS-1729 antenna bases should be enclosed in a protective box to decrease the amount of moisture leakage into the base-tuning mechanism and the base cable connections and to provide a means of relieving the strain on the connectors caused by the heavy cables.
8. All AS-1729 antennas should use the rigid section in place of the spring mount, to increase reliability and decrease the safety hazard.
9. An entirely new vhf antenna system should be designed. It should be structurally stronger than any now in service and be capable of providing a more nearly perfect omnidirectional pattern. One approach is to design the antenna to completely surround its support in a staggered array, and mount the entire structure as high as possible in the ship's superstructure.

APPENDIX A: OUT-OF-BAND VSWR INVESTIGATION OF THE AS-1729/VRC ANTENNA SYSTEM

The AS-1729/VRC antenna is a 10-foot, center-fed, base-tuned vertical whip. The antenna covers the 30-76 MHz frequency range in ten pretuned bands which may be remotely selected or manually switched at the antenna's base. It is intended to provide a VSWR of 3:1 or less over the 30 to 76 MHz frequency range when mounted on a 10-ft by 10-ft ground plane. The antenna was designed for vehicular use, but is being used on major amphibious ships for ship-to-ship and ship-to-shore vhf communications.

A theoretical analysis is presented in the text to determine the maximum range that can be expected from a vhf communications system that uses the AS-1729 for its antennas. The analysis requires the amount of mismatch loss that can be expected out of band. The investigation reported here consists of measurements of the antenna's out-of-band VSWR for each pretuned band. From the antenna's VSWR, its mismatch loss to a 50-ohm system can be calculated. The tests and results are reported here.

TEST SETUP

The antenna was mounted on an extended ground plane. The equipment and engineer were located in a pit directly below the antenna and ground plane. Figure A1 is a block diagram of the instrumentation used to measure the out-of-band VSWR of the AS-1729 antenna. An HP 8690B sweep oscillator using an HP 8698B rf unit (0.4-110 MHz) was swept from 30 to 80 MHz. The HP 5245L electronic counter was used to accurately set the 30 and 80 MHz sweep band limits. A power divider splits the (-10 dBm) oscillator output, one half going to the reference channel input of the HP 8407A network analyzer, the other half going through a directional coupler. The directional coupler offers a 6-dB loss to the power transmitting through it to the antenna. The reflected power from the antenna undergoes another 6-dB loss as it returns through the coupler to the analyzer's test channel input. The network analyzer compares the two inputs and provides a CRT display of return loss vs. frequency. An HP 7005B X-Y recorder was used to record the measurements.

TEST PROCEDURE

The test objective was to measure the out-of-band VSWR of the AS-1729/VRC antenna for each of its ten bands using the instrumentation shown in figure A1. Table A-1 shows how the ten bands divide the 30 to 76 MHz frequency range of the antenna. The manual band switch located on the antenna's tuning base does not select the band in consecutive order. The order of actual band selection, shown in table A-1, is the one referred to in the remainder of this appendix. Table A-1 also gives the figure number for the measurements of a particular band.

The out-of-band VSWR was measured by selecting a particular band at the antenna's base. The entire 30 to 80 MHz range was then swept and the

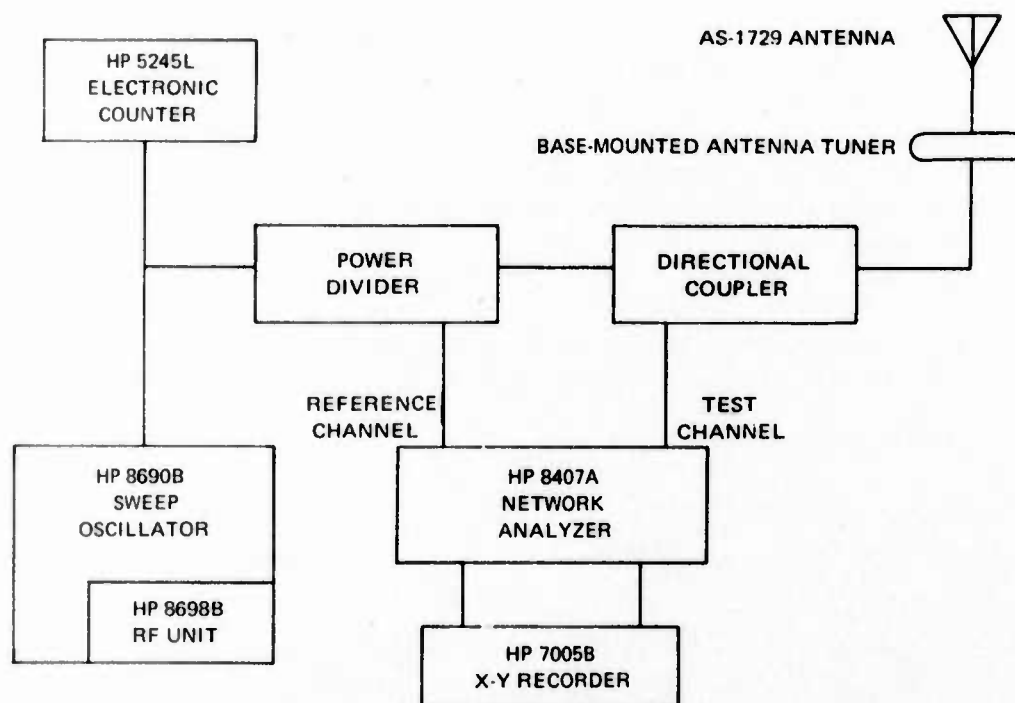


Figure A1. Test setup.

TABLE A-1. AS-1729 ANTENNA BANDS.

Band (MHz)	Band Number	Figure Reference
1. 30-33	1	A3A
2. 33-37	5	A3A
3. 37-42	4	A3B
4. 42-47.5	2	A3B
5. 47.5-53	3	A3C
6. 53-56	6	A3C
7. 56-60	10	A3D
8. 60-65	9	A3D
9. 65-70.5	7	A3E
10. 70.5-76	8	A3E

return loss for the entire range for that antenna band was measured by the network analyzer, displayed on its CRT, and recorded on the X-Y plotter. The upper frequency was set at 80 and not 76 MHz simply for ease in calibration. The X-Y plot was calibrated in VSWR using the nomograph of figure A2. Figures A3A through A3E are the X-Y plots of the VSWR measured for each of the ten bands per figure. Shown on each curve are the actual in-band locations.

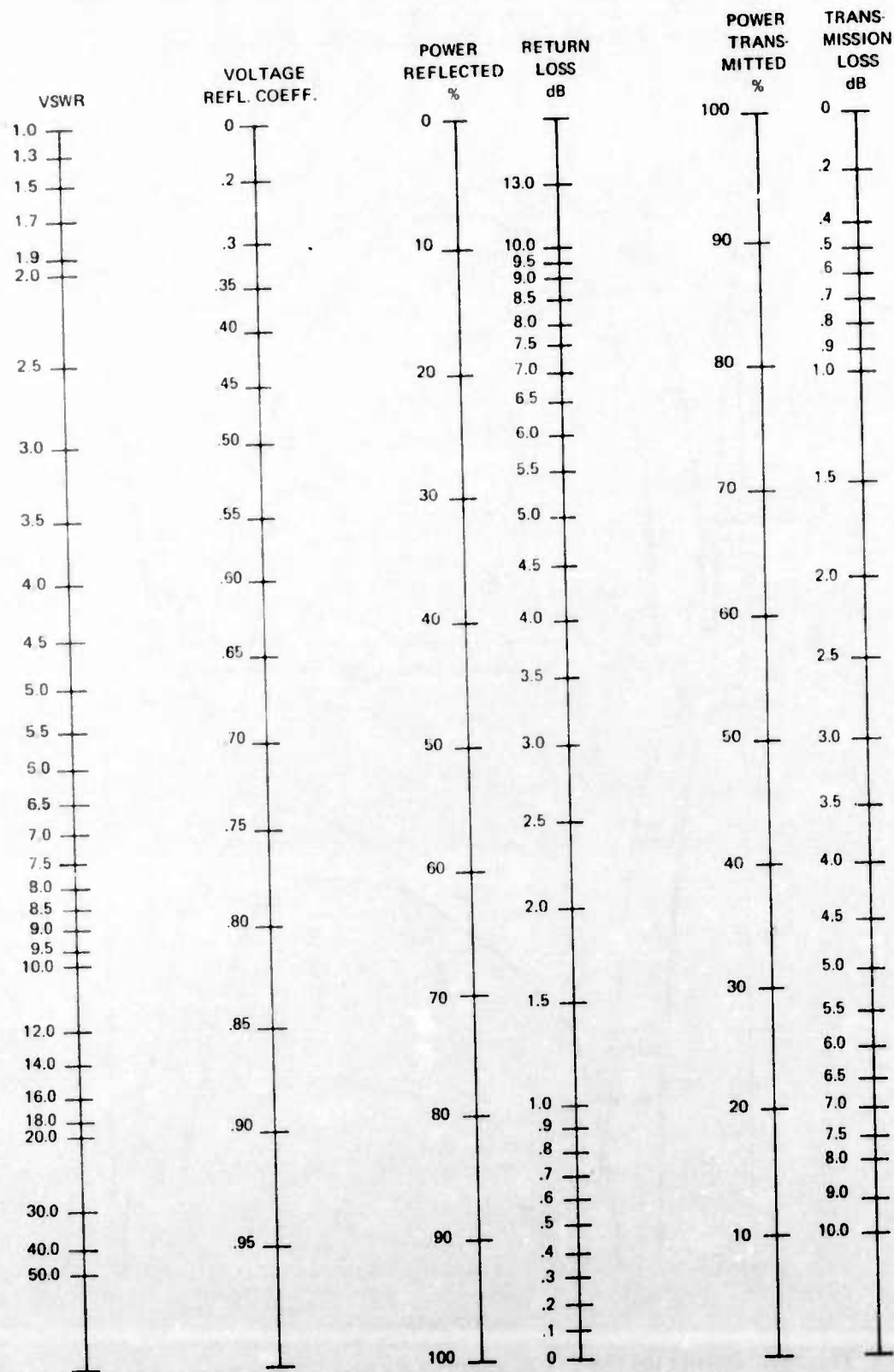


Figure A-2. VSWR nomograph.

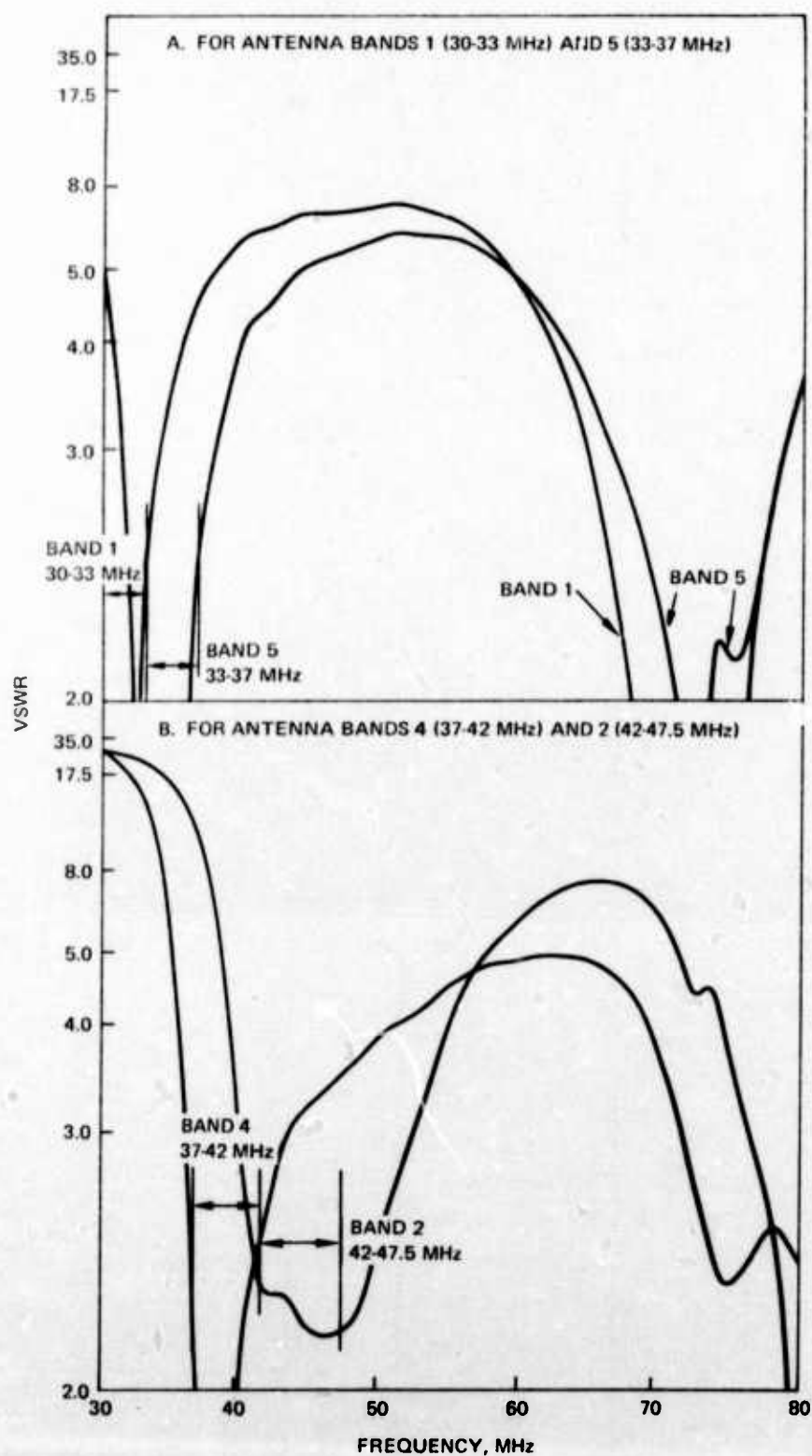


Figure A3. Out-of-band VSWR vs. frequency of the AS-1729 base-tuned, center-fed vertical whip antenna as measured over an extended ground plane using the HP 8407A network analyzer; antenna tuned to each of its ten in-band positions.

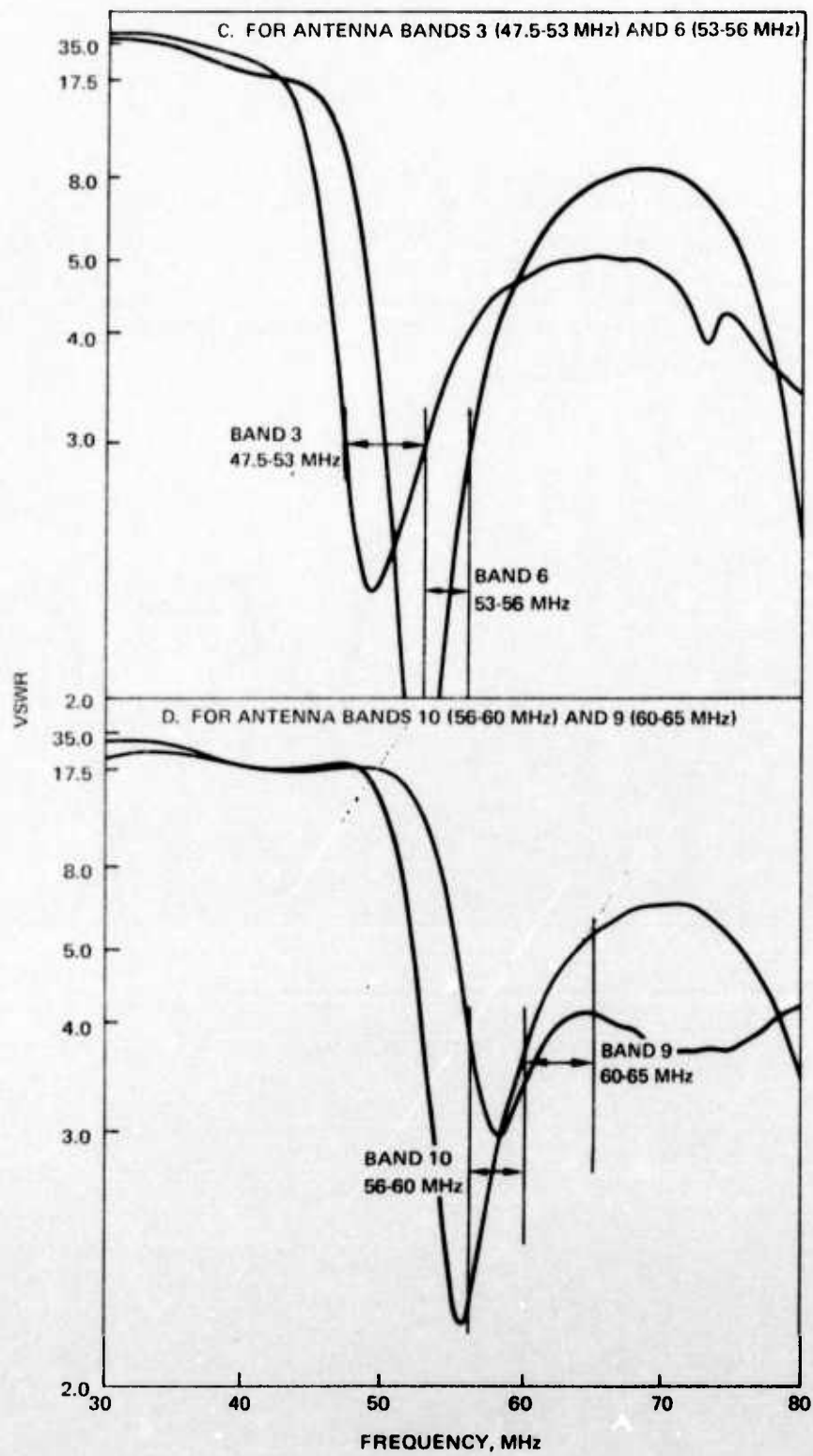


Figure A3. (Continued).

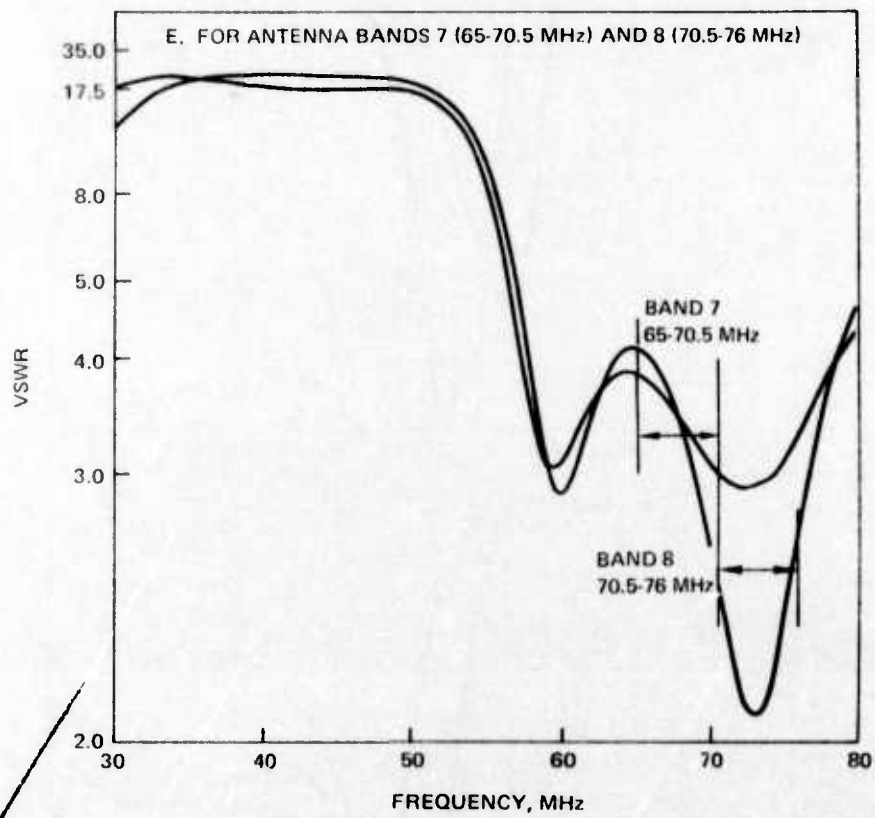


Figure A3. (Continued).

MEASUREMENT RESULTS

The VSWR vs. frequency was plotted for the antenna tuned to each of its ten in-band positions and mounted on an extended grounded plane. Five plots were made with two bands per plot. The band limits for each curve are indicated. Bands 6, 7, 9, and 10 do not have their ranges of minimum VSWR entirely within the proper band limits. Only bands 1, 4, 5, and 6 have their VSWR fall below 2:1. Band 1 has two deep excursions of its VSWR, the first its normal 30-33 MHz band, the second in the band 66-76 MHz (at the 2:1 VSWR point), or nearly its first quarter-wave multiple. When the antenna is mounted on an extended ground plane, the VSWR within each tuned band is within 3:1 except for band 7 (65 to 70.5 MHz) and band 9 (60 to 65 MHz) and the upper one-third of band 10 (56 to 60 MHz). Bands 1 (30 to 33 MHz) and 5 (33 to 37 MHz) have a VSWR of 8:1 or less for a mismatch loss of 4 dB or less out of band. Bands 3 (47.5 to 53 MHz) and 6 (53 to 56 MHz) reach a maximum out-of-band VSWR of 38:1 for a mismatch loss of 10 dB. Bands 2 (42 to 47.5 MHz), 4 (37 to 42 MHz) 7 (65 to 70.5 MHz), 8 (70.5 to 76 MHz), 9 (60 to 65 MHz), and 10 (56 to 60 MHz) have maximum VSWR's in the range of 17.5:1 to 35:1 for a mismatch loss range of 9.7 dB to 6.8 dB. The range of maximum out-of-band mismatch loss is then 4 to 10 dB.

CONCLUSIONS

These conclusions are based on the curves presented here, taken on one completely new sample antenna system which in this case was assumed to be typical. The following conclusions are made:

1. The AS-1729/VRC antenna when mounted on an extended ground plane provides a VSWR of 3.75:1 or less.
2. The maximum out-of-band mismatch loss that can be expected is 10 dB.
3. Band 1 (30 to 33 MHz) falls below a 2:1 VSWR at 30 to 32 MHz and also at 68 to 76 MHz.
4. Band 4 (37 to 42 MHz) falls below a 2:1 VSWR at 37 to 40.5 MHz and so does band 5 (33 to 37 MHz) at 32 to 36.5 MHz and again at 71.5 to 73.5 MHz.
5. Band 6 (53 to 56 MHz) falls below 2:1 from 52 to 53 MHz.
6. When the antenna is mounted on an extended ground plane, the VSWR is within 3:1 except for band 7 (65 to 70.5 MHz), band 9 (60 to 65 MHz) and the upper one-third of band 10 (56-60 MHz).

APPENDIX B: DERIVATION OF THE RANGE PREDICTION EQUATION AND A SAMPLE CALCULATION FOR MAXIMUM RANGE FOR THE AN/VCC-2, VHF-FM (30-76 MHz) ANTENNA AND RF DISTRIBUTION SYSTEM

The predicted range attainable by a communications link can be determined from the curves in figure B1. This figure displays field strength in dB/ μ V/m (ground wave) versus distance in statute miles over seawater for several frequencies, assuming 1 kW radiated power from a lossless short monopole on the earth's surface. To use the curve some assumptions are needed. The assumptions made for all systems are:

1. The received signal necessary for a maximum range is -87 dBm for multi-channel voice in a 50-ohm system for a constant 12 dB S+N/N ratio at the receiver audio output (see footnote 2 in main text).
2. The available power output of the RT-524 transceiver is 40 watts (+46 dBm).
3. No external noise, i.e., receiver noise, limits sensitivity.
4. Land/water interface effect on field strength is negligible as the link is with beach units at the edge of the seawater.

The equation for converting the given information to that necessary for using the curve is derived here.

For the receiving system:

For a ($\lambda/4$) monopole antenna over a ground plane

$$V_{OC} = E h_e$$

$$V_{OC} = E \lambda / 2 \pi$$

where

V_{OC} = open circuit voltage (volts)

E = electric field strength (volts/m)

$h_e = \lambda / 2 \pi$ = antenna effective height (meters)

λ = wavelength (meters)

Converting to dB above a microvolt (dB/ μ V)

$$V_{OC} = E \text{ (dB}/\mu\text{V/m)} + 20 \log (\lambda / 2 \pi)$$

and converting from receiver voltage to antenna open circuit voltage in dB:

$$V_{OC} \text{ (dB}/\mu\text{V)} = V_{rec} \text{ (dB}/\mu\text{V)} + 20 \log \frac{Z_{ant} + Z_{rec}}{Z_{rec}} + \alpha_T$$

where

Z_{ant} = 37 ohms, for a ($\lambda/4$) monopole

Z_{rec} = 50 ohms

α_T = cable attenuation on receive side

Therefore:

$$V_{OC} \text{ (dB/}\mu\text{V)} = V_{rec} \text{ (dB/}\mu\text{V)} + 4.8 + \alpha_r$$

After combining and rearranging terms

$$E \text{ (dB/}\mu\text{V/m)} = V_{rec} \text{ (dB/}\mu\text{V)} + 4.8 - 20 \log (\lambda/2\pi) + \alpha_r$$

For any antenna other than a $(\lambda/4)$ monopole, an additional correction factor RG_{rec} is necessary. This correction factor is the relative gain, RG , that another antenna has with respect to a $(\lambda/4)$ monopole. If the system uses a multicoupler, a term for its insertion loss, β_r , must be included. And, finally, if the system being evaluated employs the AS-1729 antenna, a term for the out-of-band mismatch loss, γ_r , is necessary. So for the receiving system

$$E \text{ (dB/}\mu\text{V/m)} = V_{rec} \text{ (dB/}\mu\text{V)} + 4.8 - 20 \log (\lambda/2\pi) + \alpha_r + RG_{rec} + \beta_r + \gamma_r$$

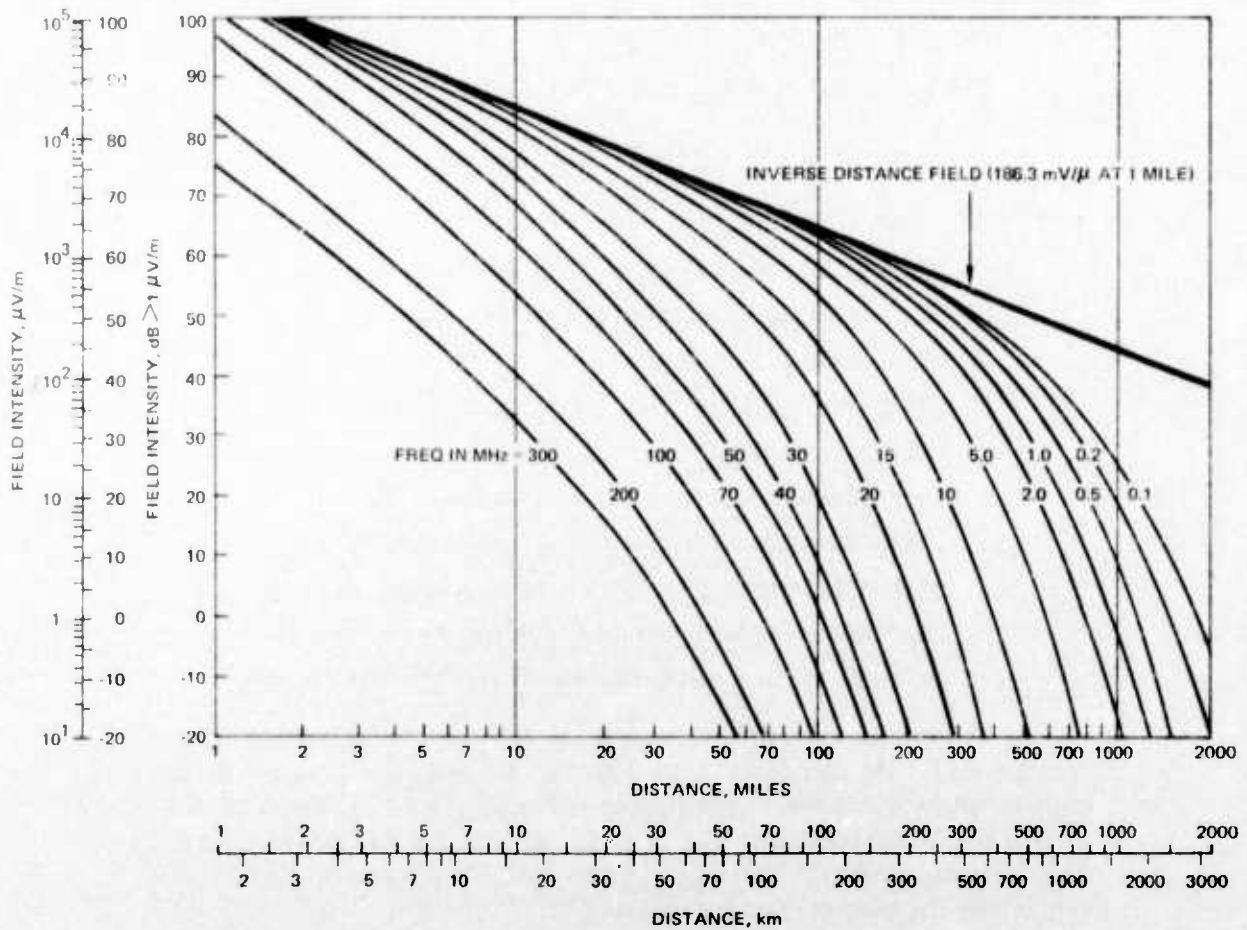


Figure B1. Field intensity at various distances as a function of frequency, with antennas at the earth's surface. Inverse distance field intensity of transmitting antenna, 186.3 mV/m at 1 mile over seawater with parameters of $\epsilon = 80$, $\sigma = 5$ mhos/m.

For the transmitting system:

Figure B1 is for 1 kW, +60 dBm, radiated power; however, the RT-524 transceiver power is only +46 dBm and there are other losses associated with the transmitting system which require additional corrections. It is assumed that a reduction of X dBm transmitter power can be compensated for by requiring X dB more field strength at the receiving antenna. If a multicoupler is used in the system, an additional term must be added to account for the insertion loss. Therefore, the correction factor for the transmitting system becomes

$$X \text{ (dB)} = 60 - 46 + RG_{xmt} + \alpha_T + \beta_T = 14 + RG_{xmt} + \alpha_T + \beta_T$$

where RG_{xmt} is the transmitting antenna's relative gain-correction factor for an antenna other than a short lossless monopole, α_T is the cable attenuation on the transmit side, and β_T is the multicoupler insertion loss on the transmit side.

The total expression for using the curve then becomes:

$$E \text{ (dB/}\mu\text{V/m)} = V_{rec} \text{ (dB/}\mu\text{V)} + 4.8 - 20 \log (\lambda/\pi) + RG_{rec} \\ + \alpha_r + \beta_r + \gamma_r + 14 + RG_{xmt} + \alpha_T + \beta_T$$

which is the range analysis, equation (1) given in the text, where:

E = electric field strength in dB/ μ V/m

V_{rec} = receiver sensitivity in dB/ μ V

λ = wavelength in meters

RG_{rec} = receive antenna's relative gain in dB/ $1/4 \lambda$ monopole.

RG_{xmt} = transmit antenna's relative gain in dB/ $1/4 \lambda$ monopole.

α_r = cable attenuation of receive system in dB

α_T = cable attenuation of transmit system in dB

β_r = multicoupler insertion loss of receive system in dB

β_T = multicoupler insertion loss of transmit system in dB

γ_r = out-of-band mismatch loss of AS-1729 antenna in dB

The predicted maximum range is calculated for rf distribution combination #3 for the matrix of figure 2 in the main text. The calculations for combination #3 are given in detail as an example because it is the most complex of the 28 combinations considered. It consists of a ship having an AS-1729/VRC antenna and CU-1857 multicoupler combination transmitting to another ship having the same combination aboard.

The calculations begin with:

Receive System

λ @ 30 MHz = 10 meters

λ @ 40 MHz = 7.5 meters

$$\begin{aligned}\lambda @ 50 \text{ MHz} &= 6.0 \text{ meters} \\ \lambda @ 60 \text{ MHz} &= 5.0 \text{ meters} \\ \lambda @ 70 \text{ MHz} &= 4.28 \text{ meters} \\ \lambda @ 80 \text{ MHz} &= 3.75 \text{ meters}\end{aligned}$$

and

$$\begin{aligned}20 \log (10/2\pi) &= 4.02 \\ 20 \log (7.5/2\pi) &= 1.5 \\ 20 \log (6.0/2\pi) &= -0.4 \\ 20 \log (5.0/2\pi) &= -2.0 \\ 20 \log (4.28/2\pi) &= -3.32 \\ 20 \log (3.75/2\pi) &= -4.48\end{aligned}$$

Cable loss, α_r , was assumed to be 1 dB across the band, which is a very close approximation.

$$\begin{aligned}\alpha_r (\text{combination \#3}) &= 20 \text{ feet (RG 58/U)} + 100 \text{ feet (RG 333/U)} \\ &= 0.72 \text{ dB} + 0.37 \text{ dB} = 1 \text{ dB}\end{aligned}$$

so:

$$\alpha_r = \alpha_T = 1 \text{ dB}$$

Multicoupler insertion loss, β_r and β_T , for the REP CU-1857 is 1 dB if the receive-transmit frequency spacing is a minimum of 1 MHz, so

$$\beta_r = \beta_T = 1 \text{ dB}$$

The antenna relative gains, RG_{rec} and RG_{xmt} with respect to a quarter-wave monopole, will be the same, as identical AS-1729 antennas are assumed here. So, from figure B2:

$$RG_{rec} = RG_{xmt} \cong 0 \text{ dB}$$

The out-of-band mismatch loss, γ_r , for the AS-1729 antenna was measured to be a maximum of 10 dB, so

$$\gamma_r = 10 \text{ dB}$$

All factors in the range prediction equation have now been given numerical values, and E (dB/ μ V/m) can be determined from this equation.

For 30 MHz

$$\begin{aligned}E(\text{dB}/\mu\text{V}/\text{m}) &= 20 \text{ dB}/\mu\text{V} + 4.8 - 4.02 (@ 30 \text{ MHz}) + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\ &+ 10 \text{ dB (worst case)} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\ E(\text{dB}/\mu\text{V}/\text{m}) &= 48.78 \\ &+ 48.78 \text{ dB}/\mu\text{V}/\text{m} \text{ from figure B1} = 43 \text{ statute miles}\end{aligned}$$

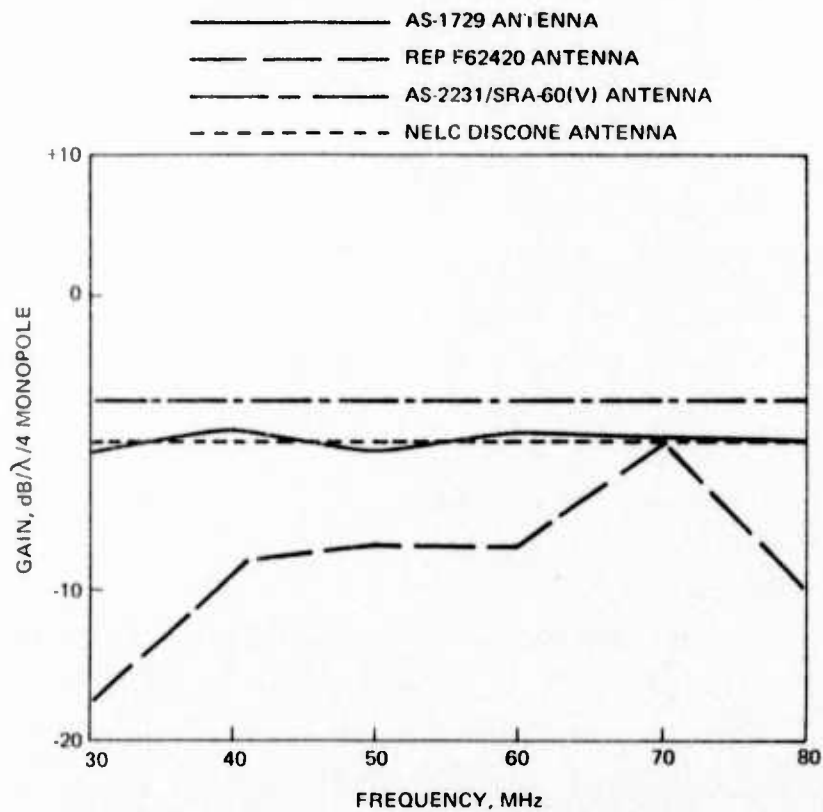


Figure B2. Gain relative to a quarter-wave monopole versus frequency for antennas mounted over an extended ground plane.

For 40 MHz

$$\begin{aligned}
 E \text{ (dB/}\mu\text{V/m)} &= 20 \text{ dB/}\mu\text{V} + 4.8 - 1.5 \text{ (@ 40 MHz)} + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 &+ 10 \text{ dB} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 E &= +51.3 \\
 &+ 51.3 \text{ dB/}\mu\text{V/m from figure B1} = 30 \text{ statute miles}
 \end{aligned}$$

For 50 MHz

$$\begin{aligned}
 E \text{ (dB/}\mu\text{V/m)} &= 20 \text{ dB/}\mu\text{V} + 4.8 + 0.4 \text{ (@ 50 MHz)} + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 &+ 10 \text{ dB} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 E &= +53.2 \\
 &+ 53.2 \text{ dB/}\mu\text{V/m from figure B1} = 22 \text{ statute miles}
 \end{aligned}$$

For 60 MHz

$$\begin{aligned}
 E \text{ (dB/}\mu\text{V/m)} &= 20 \text{ dB/}\mu\text{V} + 4.8 + 2.0 \text{ (@ 60 MHz)} + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 &+ 10 \text{ dB} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} \\
 E &= +54.8 \\
 &+ 54.8 \text{ dB/}\mu\text{V/m from figure B1} = 17 \text{ statute miles}
 \end{aligned}$$

For 70 MHz

$$E \text{ (dB/}\mu\text{V/m)} = 20 \text{ dB/}\mu\text{V} + 4.8 + 3.32 \text{ (@ 70 MHz)} + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} + 10 \text{ dB} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB}$$

$$E = 56.12 \text{ dB/}\mu\text{V/m from figure B1} = 14 \text{ statute miles}$$

For 80 MHz

$$E \text{ (dB/}\mu\text{V/m)} = 20 \text{ dB/}\mu\text{V} + 4.8 + 4.48 \text{ (@ 80 MHz)} + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB} + 10 \text{ dB} + 14 + 0 \text{ dB} + 1 \text{ dB} + 1 \text{ dB}$$

$$E = +57.28$$

$$+ 57.28 \text{ dB/}\mu\text{V/m from figure B1} = 11 \text{ statute miles}$$

Curves of range vs. frequency for this and the other 27 systems appear in figures 3A-G in the main text. All other plots were calculated in exactly the same manner as for combination #3 above, using the appropriate parameters listed in tables B-1 and B-2.

TABLE B-1. ANTENNA GAIN, RG, RELATIVE TO A QUARTER-WAVE MONOPOLE (dB)*

Frequency, MHz	AS-1729	AS-2231	Discone	F62420**
30	0 [†]	+3	0	-18
40	0 [†]	+3	0	-9
50	0 [†]	+3	0	-8
60	0 [†]	+3	0	-8
70	0 [†]	+3	0	0
80	0 [†]	+3	0	-10

*Cable loss for all systems is assumed to be +1 dB

**Mounted 10 inches above extended ground plane

[†]An additional mismatch loss must be considered when using this antenna with the CU-1857 multicoupler

TABLE B-2. MULTICOUPLER INSERTION LOSS (dB)
(β_r -Receive, β_T -Transmit).

Frequency, MHz	SRA-60	CU-1857	F64685 (4-port)	F64685 (8-port)
30	-3, -3	+1*, +1*	+7, +7	+10, +10
40	-2.2, -2.2	+1*, +1*	+7, +7	+10, +10
50	-2.2, -2.2	+1*, +1*	+7, +7	+10, +10
60	-2.2, -2.2	+1*, +1*	+7, +7	+10, +10
70	-2.2, -2.2	+1*, +1*	+7, +7	+10, +10
80	-2.2, -2.2	+1*, +1*	+7, +7	+10, +10

*For 1 MHz frequency spacing

APPENDIX C: TESTS PERFORMED ON THE RADIO ENGINEERING PRODUCTS CU-1857/TRC DIPLEXER

The VCC-2 requires two antennas which can be used simultaneously for transmit and receive. In an effort to minimize the antennas required, Radio Engineering Products (REP) designed an antenna coupler for use with the VCC-2. Some tests were performed on the antenna coupler (CU-1857/TRC).

DESCRIPTION OF EQUIPMENTS

The description of the diplexer tested is quoted from the Antenna System F61122 Instruction Book by Radio Engineering Products, dated 3 February 1970.

"Antenna Coupler CU-1857/TRC. This antenna coupler consists of four, capacity tuned, high Q, series resonant circuits. This is a unit to isolate the transmitter and receiver when using one antenna for duplex operation of a radio set. It operates in the frequency range of 30 to 76 MHz. The unit is rugged and immersion proof. Tuning controls, tuning meter and BNC coax connectors are mounted on the front panel. Construction is of cast aluminum alloy. [See figure C1.]

"The electrical characteristics of the CU-1857/TRC Antenna Coupler are:

Type of coupler	4 helical resonators, 2 section
Power capacity	65 watts per section max
Frequency range	30 to 76 MHz
Impedance	50 ohms
VSWR	1.5 max
Separation frequency	1.5 MHz min
Isolation, each section	42 dB min at 76 MHz 48 dB min at 30 MHz
Insertion loss	2.5 dB max"

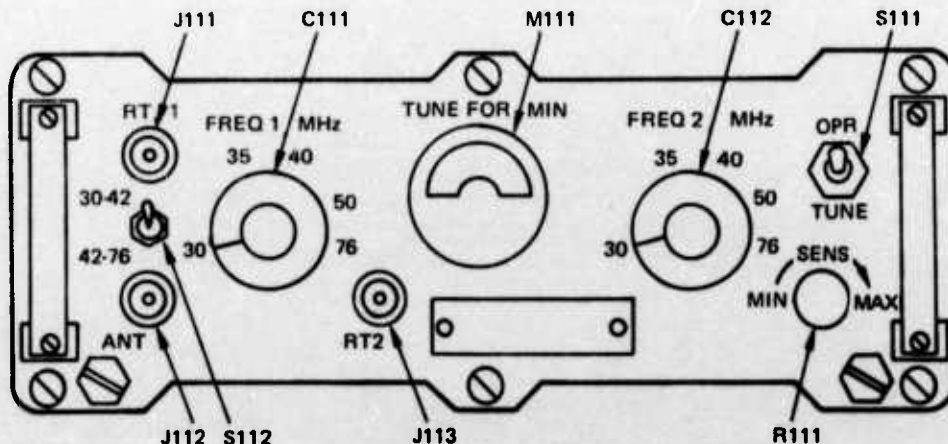


Figure C1. Antenna Coupler, CU-1857/TRC, controls and connectors.

TEST RESULTS

The tests made on the CU-1857/TRC antenna coupler were isolation or insertion loss between various ports. Figures C2A-C show the results of these measurements. All the figures were measured under the same conditions. Only the frequency of #1 was changed. The solid curves illustrate the insertion loss between the antenna and "RT-1." The dashed curve indicates the isolation between "RT-1" and "RT-2" with #2 tuned to the measuring frequency. This shows the rejection of transmitter power to a receiver front end when a common antenna is used. The measurements were made utilizing the standard substitution method with a 50-ohm receiver acting as a tuned VTVM. The results differ from the instruction book. This is probably due to the measurement technique.

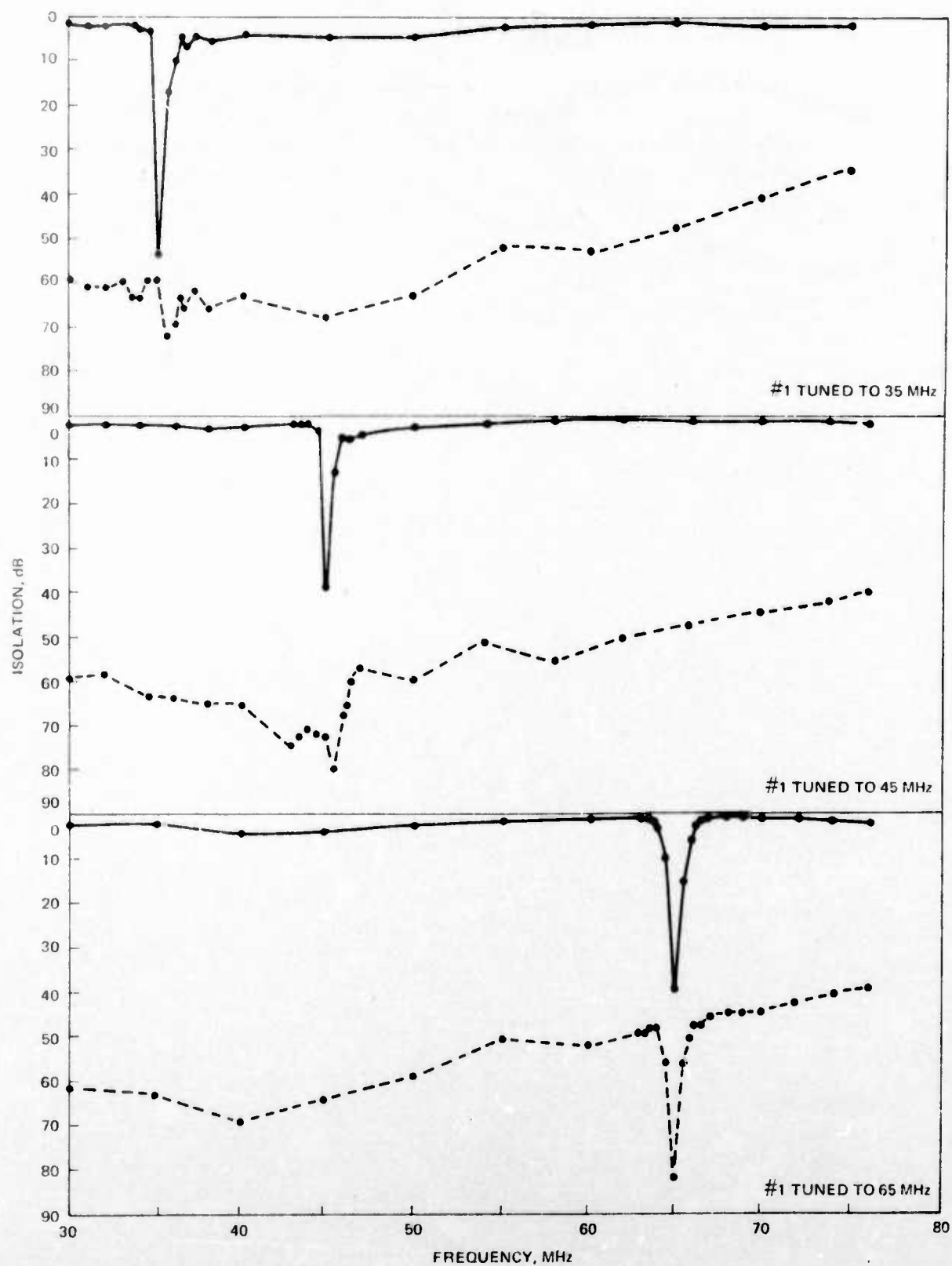


Figure C2. Isolation vs. frequency as measured on CU-1857/TRC antenna coupler between RT-1 and antenna (solid line) and between RT-1 and RT-2 (dashed line). Various frequencies of system #1; #2 tuned to measuring frequency; 50 ohms on RT-2 and on antenna.

CONCLUDING COMMENTS

These tests were made unofficially on equipments loaned from COMPHIBPAC in an effort to become familiar with the diplexer. The results are recorded for their informational value and are not intended to endorse or reject the subject equipment.

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13. ABSTRACT Report of a study of operational requirements for the AN/VCC-2 rf distribution system, a multi-channel, FM duplex system (manufactured by Radio Engineering Products) operating in the vhf band. Information was obtained by surveys of VCC-2 installations on 22 ships representing four major amphibious classes, and one heavy cruiser; and by consultation with commands having knowledge of the system. Antenna arrangements and rf distribution systems on the ships are described. Seven possible antenna and rf distribution system approaches are discussed and illustrated. These approaches are theoretically evaluated for comparison, in terms of range and performance.			

14

KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

AN/VCC-2 antennas

Rf distribution systems

Multicouplers - vhf

Vhf radios